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XXV.

SOME ENGINEERING FEATURES OF THE NICARAGUA CANAL.

By Alfred Noble, Mem. W. S. E.

(*Read February 2, 1898.*)

The great range of mountains which stretches almost continuously from the Arctic Ocean to the Straits of Magellan and separates the Atlantic and Pacific slopes of the continent has two depressions where canal routes are apparently practicable. One of these is where the American Isthmus is crossed by the Panama Railroad. The projected Panama Canal is located through it, and construction is considerably advanced. The second is in Nicaragua. No other practicable route for a canal crossing is known to exist through that extended mountain range. Of the two routes, the northern one across Nicaragua is the one which offers the most advantages to the interests of the United States, because it would be the shorter one between our Atlantic and Pacific coasts or between either of them and the countries opposite the other. It has been the subject of our diplomacy for nearly a century, and for nearly half that time has been frequently visited and explored by our engineers. At the present time a survey more extended and thorough than has been undertaken heretofore is in progress, under the direction of a United States commission.

Of even more direct interest to this society is the inspection of the route now being made by a party of leading American contractors, under the guidance of one of our most distinguished members. It seems, therefore, a fitting time to present here an outline of the engineering features of the project. It will conduce to a better understanding of the subject if notice be first taken of the general features of the region traversed by the route.

The key to the Nicaragua route is Lake Nicaragua. This magnificent body of fresh water has a length of about 110 miles,

lying in a northwest-southeast direction, nearly parallel with the Pacific Coast and at a minimum distance therefrom of 12 miles. Its maximum width is about 45 miles and its area about 2,700 square miles. These figures are only approximate; the region has never been carefully surveyed, and no two maps agree.

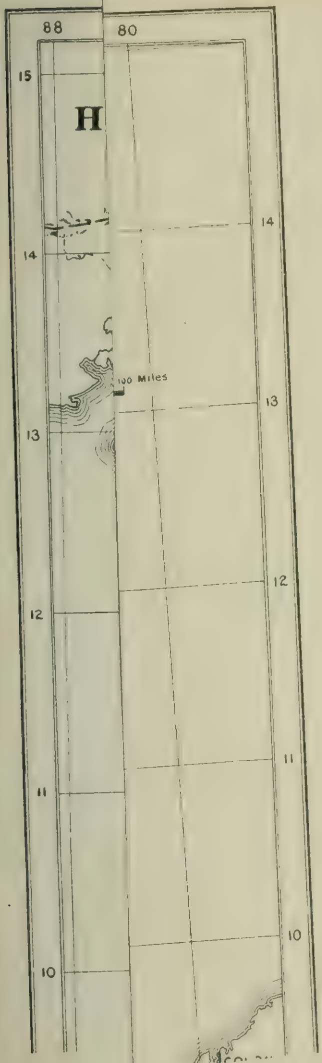
The elevation of Lake Nicaragua above mean tide is only about 102 feet at ordinary low water, and it rises in ordinary seasons about 8 feet, making ordinary high water 110. Its outlet is near the southeast end, where its waters discharge into the San Juan River and thence to the Caribbean. This lake would constitute a vast reservoir for the supply of the summit level of the proposed canal.

Northwest of Lake Nicaragua and about 25 miles distant is Lake Managua, with a length of 35 miles and breadth of 20. Its surface is about 25 feet above Lake Nicaragua, into which it drains intermittently.

About 30 miles north of Lake Managua the great continental mountain range forks. One branch passes east of the lakes and terminates on the left bank of the San Juan, about 25 miles from the Caribbean. It has a height generally of 2,000 feet and upward, and opposite the northern portion of Lake Nicaragua it has a bold, rocky outline; farther south the outlines soften, and a few miles from its terminus on the San Juan there is a low pass, through which the canal line has been located, as will appear later. The pass is known in canal literature as the "East Divide." The second branch of the continental mountain range passes west of the lakes. It is much broken. Near the head of Lake Managua it is much depressed, while on the west side of Lake Nicaragua, opposite the middle of the lake, it is almost imperceptible for a short distance, and the canal line crosses it at an elevation of only 154 feet above mean tide, or 44 feet above ordinary high water in the lake. This range is generally less bold than the one east of the lake, but it contains several volcanoes, which tower so high above the main range that they appear isolated. This range is the true continental divide; the point where it is crossed by the canal line is the lowest summit point between the Arctic and Antarctic oceans. It rises sharply south of the canal, passing into a lofty range which trends easterly in Costa Rica and forms the southern boundary of the drainage basin of Lake Nicaragua and the San Juan River. The basin of the lakes is, roughly, a rectangle, with its run much depressed in places on the western side and quite broken away in the southeast corner, at its outlet. The area of the basin is about 12,000 square miles, of which 3,300 drain into Lake Managua, the remainder directly into Lake Nicaragua—lake areas included in both cases.

The San Juan River, the lake outlet, is about 120 miles long and has a basin of about 4,000 square miles, excluding the area draining into the lakes. It has, therefore, a considerable basin of its own. In its upper course it is obstructed by several rapids. All but one are navigable by light-draught steamboats except at

Nicaragua Canal.



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Part of Central America from Honduras to the Isthmus of Panama.

low water. On the north side of the river the range separating its basin from the next one to the north is only 15 to 20 miles distant, according to the maps. The slopes are steep, and the rainfall finds its way quickly to the main river through a large number of small streams. The loftier mountain range on the south side of the river is about 50 miles distant and the streams are larger.

In the river valley near the lake there are occasional swamps, but the country is generally hilly; the hills become bolder farther down and at short intervals steep spurs abut against the river, which is therefore crooked. Except in the swamps the soil is a firm clay and the river banks are stable, this characteristic continuing to within a few miles of the sea coast. For the upper half of its course the river receives little sediment, and its bed, like its banks, is stable. About sixty-five miles from the lake it receives a large tributary, the San Carlos, which drains the slopes of some great volcanoes in the lofty mountain range in Costa Rica. In times past these volcanoes have thrown out vast quantities of sand, which the streams have gradually carried off. The San Carlos has transported it to the San Juan and filled the bed of the main river, below the junction, with shifting sand to an unknown depth. The banks, however, remain stable, except near the sea coast, where the river for a few miles passes through a region built up of sand of probably similar origin.

A few miles below the mouth of the San Carlos swamps again appear, particularly on the south side, where they are of great extent. On the north side of the river, between the mouth of the San Carlos and the pass in the eastern mountain range already referred to as the East Divide, are several small streams whose valleys are approximately parallel to the main river, and separated from it by ranges of hills of moderate elevation, through which they finally break to join the main stream. This peculiar topography has been taken advantage of in locating the present canal line.

Between the East Divide range and the coast of the Caribbean the country is flat and swampy and intersected by a network of inter-communicating streams.

The Caribbean, like the Gulf of Mexico, is essentially an enclosed sea, and the tidal range along the Central American coast is about one foot. On the Pacific side it varies greatly with the configuration of the coast, the ordinary range being about eight feet on the coast of Nicaragua.

The western coast of the Caribbean is in the trade wind region, and the rainfall is much greater than any we are accustomed to, being in general about 150 inches per year, but at Greytown, the Atlantic terminus of the Nicaragua route, it is nearly double that amount and is the greatest of record on the continent; on the west side of the lake the average annual rainfall is only 65 inches per year. Heavy down-pours are common over the entire route, the records showing 3″ in one hour, 9″ in 24 hours and

$35\frac{1}{2}$" in eight days, and there is reliable information of much heavier rains.

On the Atlantic coast and for some distance inland it rains, as a rule, every day in the year, more in some months than in a year here. On the west side of Lake Nicaragua there is a well-defined dry season of about five months, corresponding to our winter, during which little or no rain falls; but even in this section the annual rainfall is nearly double the amount here.

From this heavy rainfall there results a luxuriant forest growth, especially on low ground where one must cut every foot of the way through the dense growth of underbrush and vines. As one passes up the San Juan River the eye can never penetrate the forest more than a few feet, often not a foot. This dense vegetation, combined with the heavy rainfall, has made the exploration of the country and the location of the canal line a work of prodigious difficulty.

Although the latitude of the canal line is about 11 degrees, the temperature is not as high as might be expected. On the Atlantic Slope the ordinary annual range may be from 70 degrees to 90 degrees. Notwithstanding this apparently moderate temperature, the heat is very oppressive on account of the high humidity, the air being usually wholly saturated, and it is far more exhausting than on our western plains where the summer temperature often exceeds 100 degrees in the shade. On the Pacific Slope the temperature in the dry season is higher, often passing 90 degrees, and occasionally reaching 100 degrees. The constant and humid heat limits physical effort in a very marked degree.

The tropics are dreaded by natives of the temperate zone on account of their supposed unhealthfulness, and many localities on the American Isthmus have a bad record in this respect. The death record during the building of the Panama Railroad was frightful, and it was perhaps worse during the continuance of the orgy of the Panama Canal, although the high death rate on the latter occasion was largely due to gross mismanagement. Another example of health conditions in the tropics was afforded a few years ago during the building of a railroad in Costa Rica. A part of this work was in the low land bordering the Atlantic Coast, but the greater portion was in a mountainous country in the ascent to the continental divide, which was crossed at an elevation of about 5,000 feet. It was impracticable at first to obtain acclimated laborers on account of their employment at high rates on the Panama Canal, and large numbers of Italians and Chinese were brought in, but succumbed quickly. Work on the Panama Canal being suspended about this time, a force of West India negroes was employed and the work continued without special difficulty on account of climate.

In Nicaragua the health conditions appear to be much better than farther south. It is believed there has never been an epidemic of yellow fever in the country, although there are occa-

sional cases; there are also occasional cases of Chagres fever, which is perhaps as fatal as yellow fever, but is not contagious. Of course, there is more or less malaria. The engineers who have been engaged on the route have enjoyed good health generally, the exceptions being mainly persons of intemperate habits. During the short period of active construction on the canal a large force of natives and Jamaica negroes was employed in building a railroad across the swamp from Greytown westward to the foot hills. These men worked in water every day and under the daily rainfall, but they were taken to the seashore every night and lodged in comfortable quarters; efficient sanitary and police regulations were enforced, and the result was an entirely satisfactory health record.

Now the distance from Greytown, the Atlantic terminus of the Nicaragua route to Colon, the Atlantic terminus of the Panama route, is only 300 miles, and the difference in latitude is less than two degrees. Why, then, should sanitary conditions be much different in the two places? A very satisfactory answer is given. The Panama route is on the edge of the doldrums in midsummer, and the trend of the isthmus is here nearly parallel, not normal, to the trade wind; therefore, the wind does not sweep directly across it; it does not blow with the same persistence and force as farther north, and the pollutions of the air accumulate. In the region of the Nicaragua route, on the other hand, the trade wind blows almost every day in the year, sweeping through the low elevations along the San Juan and across the great lake to the Pacific with a gentle but constant force, preventing the accumulation of miasma and insuring a fresh supply of comparatively pure air to every part of the route.

It would not be prudent, however, to assume immunity from malarial complaints during the construction of a canal along the route. Poisonous exhalations from the ground increase in rapid ratio when freshly opened excavations are exposed to air and sun. Even in the salubrious climate of the Croton water shed malaria has been common in recent years during the construction of numerous embankments for reservoirs, and an experience far more severe may be expected in Nicaragua; but with good judgment in the selection of camps, with proper care respecting food and quarters and with adequate police supervision, it is believed the health conditions will be much more favorable than in many places in our gulf states. An adequate supply of pure water is everywhere within reach.

The entire region of Central America is subject to earthquake tremors. Apprehension has often been expressed as to their effect on the masonry and other structures of the Nicaragua Canal. There are several volcanoes in that country; among these may be mentioned the volcano Masaya, 50 miles northwest of the western division of the canal, which was in active eruption 125 years ago, the lava flow extending 10 miles; and the volcano Ometepec, on an island of the same name, only 10 miles from the

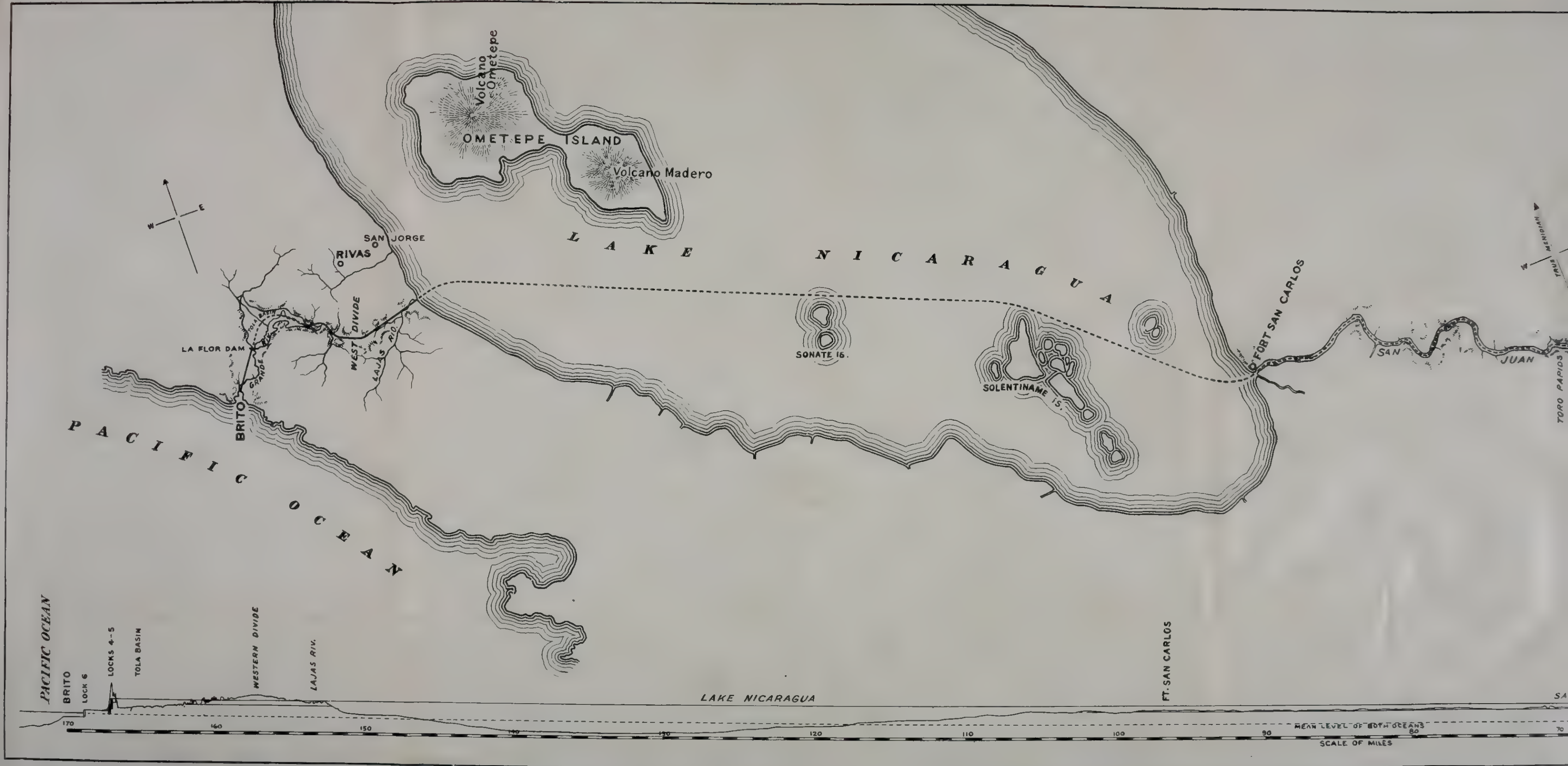
lake entrance to the western division of the canal, which has been eruption in recent years. The evidence, however, is to the effect that the tremors, although frequent, are of mild character in the vicinity of the route, like those that occur very often in California. The buildings along the route, largely made of adobe and always fragile, suffer no serious injury; there is no record of a shock like the Charleston earthquake, for example, and, in short, if it is desirable that the Nicaragua Canal be built, the remote chance of injury by earthquakes should not be deterrent.

From this imperfect statement of the natural conditions of the route, we turn to the project itself.

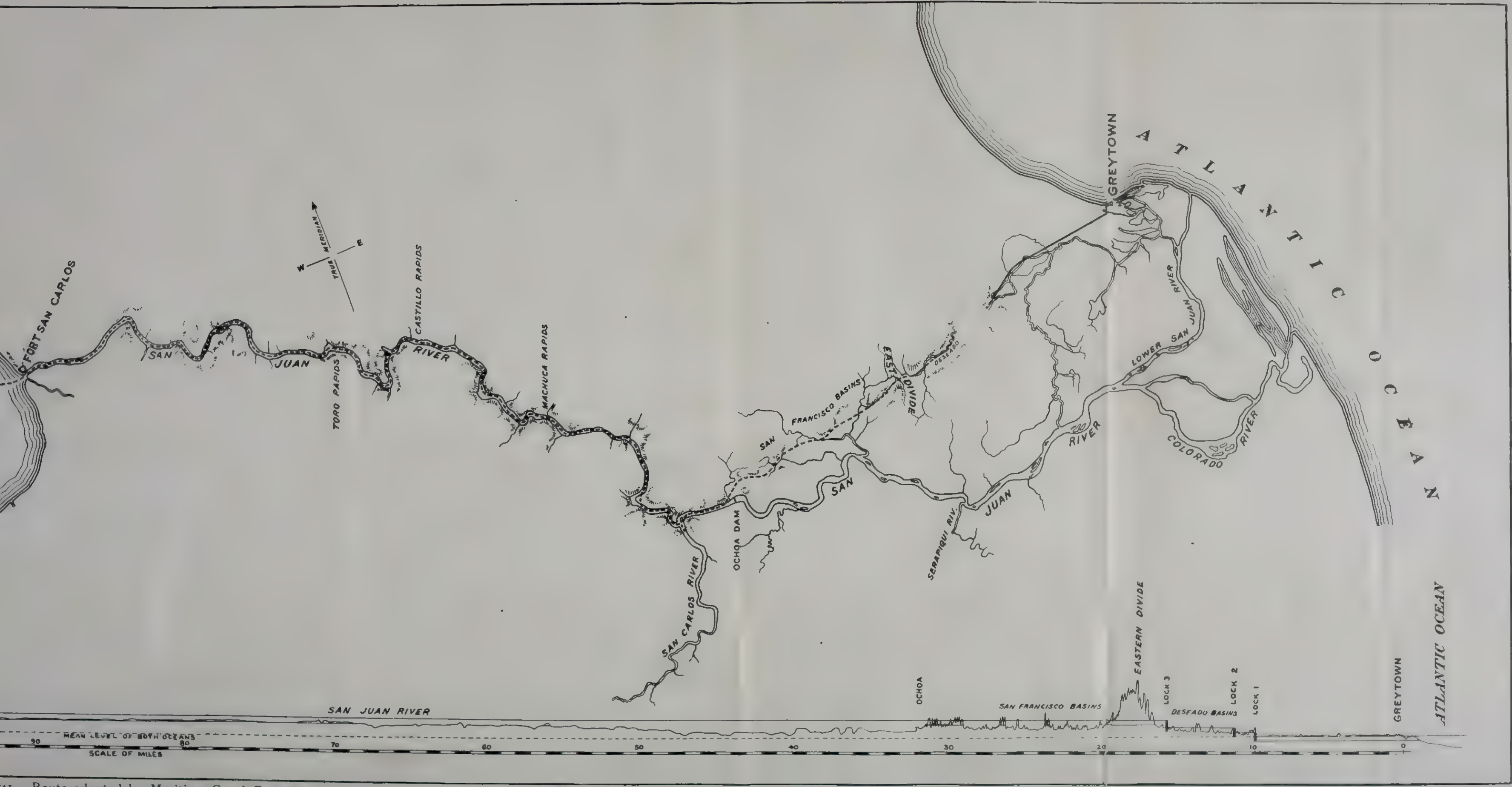
The Pacific terminus of the route is at the mouth of a small stream called the Rio Grande. It ascends this valley, which in its upper portion is quite tortuous for a distance of about 10½ miles, and then takes a tolerably direct course across the continental divide and descends the valley of the Lajas to the lake, a farther distance of 7½ miles, entering the lake 56½ miles from its outlet. After passing down the lake, it follows the river for a distance of 69 miles to a point 3½ miles below the mouth of the San Carlos. From this point to Greytown, where one of the several mouths of the river discharges into the Caribbean, the river makes a considerable detour to the southward; the canal, however, is laid across the country through the small valleys above referred to, through the pass called the East Divide and across the swampy coast region to the Carribean at Greytown. This cut-off follows a very direct line and is some 6 miles shorter than any possible route following the river. The total length of the route from the Pacific to the Caribbean is about 174 miles.

The depth of the canal as projected is to be 30 feet in the terminal harbors and also in the great rock cuts in the East and Continental divides and in the channel which is to be excavated at the lower end of Lake Nicaragua; elsewhere the depth is to be 28 feet except in certain short earth sections, where it is to be 30 feet at the center of the channel, gradually reducing to 28 at the foot of the side slopes. The bottom width of channel is to be 120 feet in the sea-level portions, which are really extensions of the harbors; 80 feet in other earth canal sections; 125 feet where excavation is required in the San Juan River; 150 feet where excavation is required in the open lake, and 100 feet with vertical sides up to 5 feet above water in the rock cuts across the divides. The locks are to be 70 feet wide and 650 feet long.

A channel depth of 28 feet for such long distances as would be found here would afford navigation for a ship drawing about 26; the same ship would draw in salt water about 25; it is evident that such a canal could not be traversed by ships of the largest class, and consequently the greatest possible reduction of freight rates for the produce of our Pacific Slope could not be obtained. It must be remembered, however, that this ruling depth was proposed for a canal intended to be purely a private commercial en-



NICARAGUA CANAL. Route adopted by Maritime Canal Company—189



…AL. Route adopted by Maritime Canal Company—1890.

terprise like the Suez Canal; it was possible and was in fact intended to increase the canal depth to 30 feet as soon as earnings should permit. It must be remembered further that since this project was formed there has been a great increase in dimensions of ocean ships and that the project did not appear as inadequate then as it does now.

If the canal is to be undertaken by the United States, for which an effort is being made, its dimensions should be enlarged so that commerce through it may have full benefit of the latest developments in ship building; this consideration would fix the depth at not less than 30 feet.

It will probably not be questioned that if our government is to undertake this work, the canal should afford passage for our largest warships. This would require wider locks, a change which would add little to the cost.

A difficult question in most canal projects is the water supply for the summit level. Lake Nicaragua provides abundantly for this one.

Along the greater part of the sailing route in the lake, the depth of water is ample for any navigation, but for several miles near the outlet it is shallow and a channel will have to be dredged. It is easy to see that if the lake surface can be raised permanently a part of this dredging can be avoided. The advantage of thus raising the lake level was seen clearly forty-five years ago by Col. Childs, who surveyed the route for Commodore Vanderbilt. On the other hand, there is a limit beyond which it is not permissible to raise the lake; the most fertile part of Nicaragua lies along the lake shore, much of it but little above the present lake surface; indeed, it is said on good authority that at extreme high water a considerable part of Granada, one of the largest cities, is submerged. The ordinary low water level of the lake being about 102 feet above meantide, Col. Childs proposed to build a dam across the San Juan River, at Castillo Rapids, 37 miles from the lake, and raise the level to a minimum elevation of 108. The present project provides for a dam 69 miles from the lake, at a point called Ochoa where the canal line leaves the river, and thereby to maintain the lake at a minimum elevation of 110. The effect would be, not only to reduce the amount of dredging in the lake but in the upper reaches of the river as well, still requiring, however, deepening the channel for a distance of 14 miles in the lake and 30 miles in the river.

The proposed new minimum elevation of the lake, 110, corresponds closely with present ordinary high water. It is not known definitely what would be the maximum permissible stage. Assuming for illustration merely that this would be 113, the permissible storage during the rainy season would be 3 feet; the storage under present conditions is about 8 feet in ordinary seasons with a maximum of perhaps 10 in unusual seasons, and the maximum must be provided for; it follows that the river must discharge during the rainy season an amount greater than its

present maximum seasonal discharge by say 7/10 of its present storage, and this with the channel obstructed by a dam. These conditions present a most interesting hydraulic problem; it has not been solved; hardly any of the data needed have been collected; doubtless the present commission will supply this need and solve the problem or determine what changes in the storage conditions are necessary to make it solvable. The feasibility of the project will not be affected by such changes, but the cost may be in some degree.

In order to regulate the discharge of the river, and thereby to control the lake level, it is proposed to build great controlling works in the ridge which bounds the San Carlos drainage basin on the east and with which the Ochoa dam is to connect. These controlling works will have to provide not only for the discharge from the lake, but also for the floods coming from the area which drains directly into the river between the lake outlet and the site of the dam. This area, as nearly as can be determined from the imperfect maps, is about 2,300 square miles. The discharge at Ochoa at high flood has never been measured, and estimates differ widely. The Nicaragua Canal Board of 1895 estimated the possible maximum at 125,000 to 150,000 second feet from the very meager data available. This seems very large, but a few instances may be cited to support it.

The maximum discharge of the River Lehigh, in Pennsylvania, estimated from high water marks, is given by Mr. C. C. Vermeule* as 73,000 second feet from an area of 1,332 square miles.

The same authority* gives the maximum discharge of the Raritan, at Bound Brook, N. J., as 52,000 second feet from an area of 879 square miles.

Mr. Francis Collingwood† estimated the maximum discharge of the Chemung River, at Elmira, N. Y., in June, 1889, at the time of the Johnstown flood, at 138,000 second feet from an area of 2,055 square miles. This area, it will be observed, is less than the estimated area of the San Juan basin above Ochoa, and the flood discharge is quite as great in proportion. This comparison leaves out of consideration the amount contributed to the San Juan by Lake Nicaragua.

The rainfall conditions in the San Juan basin correspond more closely with those in some parts of India than with those of our eastern states, and better comparative data are offered by the rivers of that country; for example, the Kali Nadi, from which a discharge of 132,000 second feet‡ has been observed from an area of 2,377 square miles; the Ramghur, with a discharge of 102,000 second feet from an area of 1,000 square miles; the Tambrapurni, with a discharge of 125,000§ second feet from an area of 1,750 square miles; the Damooda, with a discharge of 194,000¶ second

* Report New Jersey Geological Survey, 1894. Vol. III.
† Report on Protection of City of Elmira from Floods.
‡ W. A. Thelwall, in M. P. I. C. E. Vol. 95.
James Craig, in M. P. I. C. E. Vol. 80.
§ Mullin's Irrigation Manual.
¶ A. A. West, M. P. I. C. E. Vol. 27.

feet from an area of 3,000 square miles, and the Krishna with the enormous measured discharge of 118,000* second feet from an area of only 345 square miles.

A single example will be cited from a district nearer the one in question. It is the Chagres River at the Isthmus of Panama, where the annual rainfall is about one-half as great as in the San Juan basin; probably the slopes are not as steep as in the latter basin; the soil is similar. Col. A. L. Rives, a well-known American civil engineer, for some years manager of the Panama Railroad, noted a discharge of 75,700 second feet. The drainage area cannot exceed greatly 1,000 square miles.

From these examples it will appear that the estimate of the maximum flood in the San Juan is not excessive. The extreme floods are of short duration, and after the construction of the Ochoa dam will be equalized to some extent by the basin formed by it; it is obvious, however, that the controlling works must be of great magnitude, even when compared with those of the Chicago Drainage Canal.

At the site of the Ochoa dam the river banks are clay but the bed is sand. Borings have been made 18 to 24 feet into the sand without passing through it, and its depth is unknown. The dam is intended to raise the river surface 65 feet. If the foundations were of rock a masonary dam would undoubtedly be built, but is probably impracticable at the site chosen. No better site has been found in the vicinity.

The plan adopted for the dam is to form a mound of loose rock across the river by dumping into the flowing stream from cableways; the rock is to be in large masses, five tons or more in weight. It is expected that as the sand is scoured out around and under the stones they will sink into the bed and finally become stable. It is also expected that the width of the dam at the base will be several hundred feet. Such a dam would not hold water, but it is intended to dump on the up-stream side smaller stone, gravel and clay until the interstices in the rock mass become filled and the whole structure sufficiently water-tight.

It is believed that this plan was first proposed for this site by the late Arthur M. Wellington; he supposed, however, that solid bed rock was overlaid by no great depth of sand, and that the flood discharge of the river was not far from 12,000 second feet. Whether his endorsement would have been given for a maximum discharge of 10 or 12 times that amount and sand of great depth can only be conjectured. It seems to the writer that the period of greatest hazard to such a dam would be when nearly completed; if one of the great floods should then occur and a discharge of 125,000 second feet should pass over the dam and rush down the down-stream slope, it would have sufficient force to move heavy masses of rock and the danger of immediate destruction would be extreme. If the dam were once built to such a height that the water could not reach its top but would be cared for by the con-

* A. A. West, M. P. I. C. E. Vol. 27.

trolling works, the danger would be less. It could be strengthened indefinitely by adding more material, and if maintained a few years would merit confidence.

With the dam built as stated, the summit level would be maintained in 69 miles of river. It is proposed to carry it still farther by damming the outlets to the valleys between Ochoa and the East Divide, forming several small basins, called the San Francisco basins, from the name of the principal stream crossed. The summit lock is to be located on the east side of the divide within 17 miles of the Caribbean. When this route was first advocated it was supposed that only a single dam would be required at the outlet of these basins, but later surveys showed that there would be 67 between Ochoa and the East Divide and 23 between the dam and the mountains in Costa Rica, the aggregate length being about 7½ miles. These dams or embankments are to made of clay. Several of them traverse mud swamps where the soft ooze will have to be removed to a depth of 30 feet or more and the embankments at these places will have a height of 100 feet. These great and extended embankments are justly considered to be dangerous features of the East Divide route.

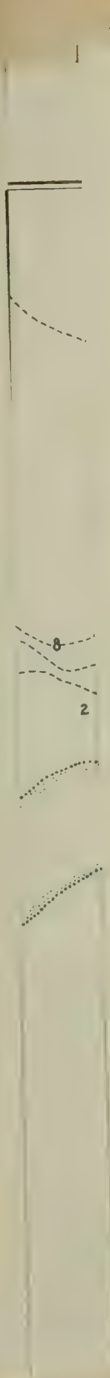
Across the East Divide the line follows the valleys of two creeks, but cuts the interlocking spurs, around which the valleys wind. The line is therefore laid across a succession of steep hills. The maximum depth of cut is 328 feet. In a distance of three miles there will be 3,400,000 cubic yards of earth and 8,300,000 cubic yards of rock excavation. The earth, which is clay, will be needed in the embankments between the divide and Ochoa; the greater part of the rock suitable for those purposes will be required in the Ochoa dam, the Greytown jetties and in concrete for locks and sluices in the vicinity.

The descent from the summit level to the Caribbean is to be made in three or four locks placed at suitable points in the eastern slope from the East Divide. The sea-lock will be about 11 miles from the sea; immediately east of it the ground is only 15 feet above sea level and the canal to the sea coast will be made by dredging through clay, mud and sand.

The route through the East Divide is one of several alternatives, other routes following the river more or less closely. The surveys now in progress will doubtless determine which is the best. The East Divide route is believed to be practicable, but there are great inherent risks.

The country along the eastern division, like all Central America, is of volcanic origin. The sand is disintegrated volcanic rock; the clay, geologists tell us, is decomposed volcanic rock; the rock itself is of all degrees of hardness, from telepetate, a semi-indurated material, to the hardest trap. Soft rock underlies hard in places and the character changes in short distances, both horizontal and vertical; layers of soapstone are said to exist, and their existence is also denied.

For an understanding of the problem of Greytown Harbor it is



On account of the eddy north of Greytown and the resulting

Greytown Harbor.—From a Survey made by George Peacock, 1832, showing accretions to Sand Spit to 1859.

necessary to note the formation of the sea coast and the action of waves and currents thereon.

About 20 miles from the sea the San Juan divides into two branches; about 4/5 of the discharge is through the right hand channel, the Rio Colorado, which empties into the sea about 18 miles south of Greytown; the left hand channel, called the lower San Juan, discharges into the lagoons in the vicinity of Greytown and the water reaches the sea through shifting outlets across the strip of sand which separates the lagoons from the sea.

Reference has been made to the San Carlos as a sand carrier. The San Juan receives another large tributary, the Serapiqui, about 25 miles lower down, which also has its sources on the slopes of the lofty volcanoes of Costa Rica and has also been a sand carrier. With the sand brought down by these tributaries the San Juan has advanced the shore line at its mouths several miles. Doubtless other streams discharging into the sea south of the mouths of the San Juan have their sources in the same range, possess the same characteristics and have contributed to the same result.

The streams discharging into the sea north of the San Juan appear to carry less sand and the shore line is apparently advanced less rapidly. This causes the conformation shown on the map, the two stretches north and south of Greytown being connected by a short section having a direction nearly east and west. Behind this short section lie two lagoons, once united, into which the lower San Juan discharges through several mouths.

The movement of sand along the coast from beyond the Colorado mouth to Greytown is from south to north. North of Greytown there appears to be an eddy—as might perhaps be expected—and the sand movement is from north to south. A century or two ago, perhaps, a horn-shaped projection or spit had formed on the continuation of the south coast line, overlapping the east and west section, and in 1832 had extended so far that there was a fair harbor behind it. As this spit advanced it deflected toward the west, and in 1848 had approached within one mile of the north coast line, leaving sufficient width of entrance for ships, and affording an excellent harbor inside. In 1860 the spit joined the opposite shore; Greytown harbor was closed and became a lagoon.

Behind the present Greytown lagoon are other lagoons which were probably harbors in their time and were closed in the same way

In order to restore Greytown harbor it is proposed to build a jetty from the shore line in front of Greytown lagoon out to deep water and dredge a channel on the lee side of it. The jetty is located on the east and west section of coast; it can, therefore, be given a direction nearly north and south, so as to protect the entrance from the prevailing northeast trade. This jetty will be a sand catcher and will probably require occasional extension.

On account of the eddy north of Greytown and the resulting

sand movement from the north toward the harbor, it is probable that a shorter jetty will be required on that side of the harbor entrance. The harbor area is to be about 240 acres, and is to be formed in the lagoon by dredging.

The distance in an air line between the mouth of the Lajas, on the west side of Lake Nicaragua where the canal line leaves the lake, to the Pacific at Brito where the canal line reaches the Pacific, is about 13 miles. By the canal line the distance from the 30 feet contour in the lake to the 30 feet contour in the Pacific is 18 miles, the increase of distance being due mainly to curvature in the line.

At a distance of 5 miles from the lake the line crosses the continental divide where the maximum depth of cut will be 74 feet; 2½ miles beyond this it enters the narrow and crooked valley of the small stream Rio Grande; along this distance of 7½ miles the slope of the ground is everywhere easy, and during the dry season the plant adopted on the Chicago Drainage Canal could be used as readily as here; the ground becomes soft, deep mud in the wet season. The narrow valley, which may be called the gorge of the Rio Grande, continues about 1¾ miles, and then the valley widens to a mile or more for a distance of 4½ miles, when it again narrows to 1,600 feet. At this point, called La Flor, about 4 miles from the Pacific, it has been proposed to build a great rockfill dam which would terminate the summit level on the Pacific side. Borings taken at the site show that such a dam is probably impracticable; this, however, is not a matter of moment. An alternative proposition is made for terminating the summit level with a lock and weir at the outlet of the Rio Grande gorge; an ordinary canal can then be carried down the valley with four locks at suitable points; this is a perfectly feasible proposition.

The rock to be excavated in the Western Division is similar to that in the East Divide, but the earth is generaly more sandy except in the vicinity of the divide; there the mud becomes almost impassable during the wet season; during the dry season deep cracks three or four inches wide form in it.

At the Pacific terminus the valley of the Rio Grande is about 1-½ miles wide. On each side the limiting range of hills terminates in a rocky promontory. The one on the south side barely reaches the general coast line; the one on the north side projects into the sea about ⅓ mile. That the movement of sand along the beach is to the north is shown by the fact that the Rio Grande is forced to the north side of the valley; that it is not great is shown by the fact that the coast line has not been advanced to the end of the northern promontory. The harbor is to be somewhat like that at Greytown; jetties are to be built to protect the harbor entrance, and a harbor area is to be made inside the present shore line by dredging.

The total length of the route has been stated in the first part of this paper as 174 miles; this is subject to revision after the

completion of the careful surveys now inaugurated. Of this distance, excavation will be required for 80 to 85 miles. The total cube of excavation for the entire work is approximately 102,-000,000 cubic yards of which

much.

There are two or three features about the canal as described in

F... - Survey made under direction of Nicaragua Canal Board—1895.

completion of the careful surveys now inaugurated. Of this distance, excavation will be required for 80 to 85 miles. The total cube of excavation for the entire work is approximately 102,000,000 cubic yards of which—

56,000,000 cubic yards is dredging;
27,000,000 cubic yards is earth above water;
1,000,000 cubic yards is mud below water requiring pumping;
16,000,000 cubic yards is rock which can be removed above water;
and 2,000,000 cubic yards is rock which must be removed by sub-aqueous methods.

Other large items are—

10,000,000 cubic yards of earth embankments;
2,000,000 cubic yards of rock fill;
2,200,000 cubic yards of stone in breakwaters;
1,000,000 cubic yards of slope walls;
1,300,000 cubic yards of concrete in locks and sluices; a large amount in addition will be required in weirs.

There will also be large expenditures for lock gates and equipment; sluice gates and machinery; weirs for the great controlling works and movable dams therefor; and the hundred other adjuncts of a great project.

The quantities just given are those of the Nicaragua Canal Board of 1895; with this exception the project described is the latest one of the Maritime Canal Company.

The aim of the writer in preparing this paper has been to present to the society an outline of the leading engineering features of the enterprise. Many structures of great extent and interest required for its full development have been passed over without mention or with bare reference, because of less importance than the more striking ones mentioned. As far as possible, questions in controversy have been excluded; but when of necessity referred to, as, for instance, the San Juan floods, the reasons for the ground taken have been given.

Some of the constructive features may be criticised as involving much hazard. Some hazard is inherent in all great work where water is to be controlled; possibly it may be reduced greatly in this case by a better location and improved plans resulting from the surveys and studies now under way; but if this cannot be done, it must be met by unusual precautions in design and construction. The writer does not doubt that a canal can be built and successfully maintained for any navigation by the Nicaragua route.

DISCUSSION.

Mr. George S. Morison: I do not feel as if, after so carefully prepared a paper by a man who is so thoroughly familiar with that country, any outsider who has never seen it could say very much.

There are two or three features about the canal as described in

this paper which call for exceedingly careful consideration and some timidity in action.

The first of these is the basin made by the Ochoa dam and by the San Francisco and San Carlos lines of embankments, lines which I think Mr. Noble stated are 7½ miles long and which cover a much greater length of country than that, there being separate embankment walls which support the entire summit level of the canal, including the increased height of Lake Nicaragua. A failure on any such line of embankments would be an extremely serious thing, and while I have no doubt that such a line of embankment could be made and that such a line could be maintained, it would seem at first sight as if a company, and still more a government, could afford to pay a very large amount to avoid any such conditions; and if another route could be found which avoided any such elements of contingency, even though that other route added a good many millions to the cost of the canal, it would be advisable to adopt it; this would be especially the case were it a government work, because in case of war or anything of that kind, the long range of embankments would be something which it would be comparatively easy to destroy, and once destroyed, it would be a very slow thing to restore. I take it, if one of the embankments were broken, the break would not extend beyond the limit of the single embankment, but it would be a thing which it would take a great while to recover from.

The route of the canal between Lake Nicaragua and the Pacific, I have always understood, is a comparatively simple problem. I believe there has been another route talked of, running more to the northwest, or what is supposed to have been the old outlet of Lake Nicaragua. It is also my understanding that the eastern route, through the San Francisco basin, is a radical departure from any of the earlier plans of the canals, and that the other lines followed down the valley of the San Juan river. It certainly would be a great advantage to avoid going down that valley. It would seem, however, that only a portion of that advantage was secured when the river is used below the mouth of the San Carlos. If the deflection from the river could be made above the mouth of the San Carlos, it would apparently remove one of the greatest difficulties that due to the discharge of a great silt-bearing stream. Of course, that is a matter that can only be suggested and can hardly be spoken of, and it must depend entirely upon what careful surveys would show to be possible.

Two points have been raised by Mr. Noble as possible difficulties. The effect on the country surrounding Lake Nicaragua if the canal is constructed on the present proposed scheme. It would seem at first sight as if the cost of leveeing the greater part of that country surrounding the lake (levees would apparently have to be but a few feet high and to act only for a small portion of the year) would be a comparatively small thing compared with some of the other features of the canal. I may be

entirely wrong about it, but it is a point that occurred to me as the paper was being read. Another point I would like to ask about is, whether it might not be possible, by a series of jetties, not built all at one time, but successively as needed, which should be some distance east or south along the coast from Greytown harbor, to keep the action of the sand far enough away from the harbor to give immunity to the harbor itself, though the harbor would have to be opened and maintained by more or less dredging.

There is one other thing that is of a more general character, and that is the dimensions of the canal. It hardly seems possible to fix any dimensions now which would not be changed before a great while. Freight-carrying steamers are now being built over 600 feet long; one passenger steamer is now being built more than 700 feet long, and large Atlantic freight steamers are following very closely on the lengths and the beam of the passenger steamers. They are considerably exceeding the draft, and, of course, they have no fine lines and have a very much greater carrying capacity. Whether there is enough economy in these extremely large ships to provide for anything more than now exists in such a canal seems to me by no means proven. On regular lines of traffic, where a few such ships take the place of a great many smaller ships, they may prove profitable; when on a long route such as would make use of the Nicaragua Canal, they might not be as serviceable as smaller ships. I think these extremely large ships are in use now only in the North Atlantic, and although there has been a considerable increase in tonnage elsewhere, and large steamers run to Australia and through to eastern points, they are not yet nearly as large as on the North Atlantic.

Mr. Noble: I could not say whether the levee along the shore of Lake Nicaragua would be practicable or not. Crops are grown there twelve months in the year. The natural drainage of the country, of course, would have to be taken care of in some way, and it is possible this might offer much difficulty.

As to the jetties or groins along the coast east and south of Greytown harbor, that is a practicable idea. That is one of two or three ways of taking care of the sand movement. There has also been an erosion on a portion of the coast. During the last twenty or thirty years the shore line on the salient east of Greytown has receded several hundred feet and at other points has advanced.

The Chair: I see Mr. Sheldon; we would like to hear from him.

Mr. Henry I. Sheldon: I would rather be excused from saying anything, except to state, from my own close familiarity with the country there, that the lecture has been not only very entertaining, but extremely and wonderfully instructive. I do not know that I have heard a single proposition advanced this evening which I would care not to see stand.

The Chair: I would inquire of Mr. Noble regarding the quality and quantity of timber in that section?

Mr. Noble: There is an abundance of timber in that country, a great deal of it is of palm-like character, simply a shell of hard material and a soft core inside. Those trees grow to a height of 100 feet or more. There are a number of soft woods which are straight enough to be of some use in building if they had sufficient durability, but a great many of them decay in a year in that climate. Then there is quite a variety of hard woods; some of them would destroy an axe long before the axe could destroy the tree. They could be made use of if there were some way of dressing the wood. There is a small amount of timber that is very useful for railroad ties, but as a general thing the timber is worth little. In the northern part of Nicaragua there is quite a pine district, and quite a quantity of that pine was brought down and used in railroad ties. That timber decayed almost totally in a few years. The climate acts very rapidly on wood.

Mr. John Ericson: I would ask how long those piles that were shown in the picture had been in place?

Mr. Noble: The view was taken about four years after the piles were driven.

Mr. Ericson: What caused the destruction at the water line?

Mr. Noble: The teredo. All drift timber along the coast is thoroughly honeycombed with teredo.

Mr. Isham Randolph: Has creosoting ever been tried as a safeguard against the teredo?

Mr. Noble: I think the action of the teredo is more vigorous the warmer the water. At Galveston they have had large experience with creosoted timber, and they found that pine creosoted with 25 pounds of dead oil will last a number of years; the timber in the Greytown jetty was creosoted with wood oil, in the proportion of 16 pounds per cubic foot, which seemed to be about the proportion the teredo favored.

The Chair: I would ask how they could reach the inner portion of the country for construction.

Mr. Noble: I presume the first step would be to create a harbor sufficient for the entrance of ships of light draught; the next would be the construction of a railroad along the greater part of the line. There are extensive swamps across which it would be impracticable to transport materials unless a railroad were first built.

The Chair: With metal ties, I suppose?

Mr. Noble: There is some local wood from which railroad ties could be made, and I presume that instead of metal they would even import creosoted pine from the United States. That was done to some extent for the short line of railroad built near Greytown; those ties had decayed considerably in some three or four years, but were still serviceable.

Mr. Randolph: A case came to my notice where, to protect the piles from teredo, they slipped vitrified pipe over the pile

and then filled in with concrete. That is the only case I saw them doing that; I do not know how it operated, and whether it was successful or not.

Mr. Noble: That measure was taken because creosoting failed there. The railroad company (the L. & N. R. R.) had some very extensive creosoting works. I do not know how that experiment turned out. I have seen nothing of it since reading the article describing how it was done.

Mr. Morison: I do not know what they have done lately. There have been a good many methods tried for protecting piles from the teredo. In a method which I saw about a year ago—I do not know that I can describe it exactly—the pile was coated with tar and tarred felt, which was supposed to make an impervious coat, and the tar was sanded, which was generally supposed to make an arrangement that the teredo would not like to work in, and then it was battened with strips of redwood, the strips of redwood being closed together, and then it was again tarred outside of the batten. All of the tar fittings are based on the general principle that if a teredo does not get a chance to start, he never can do any harm, but, if the teredo can find a little hole to work in, it is gone. The creosoting principle goes a little further and provides that he will not have the right kind of food to live on when he does get started. There are all kinds of methods by which a teredo gets into a creosoted pile to which sufficient attention has not been given. If a creosoted pile is allowed to become checked before it is driven, those checks may go in farther than the creosote, and the teredo has only to get into a check and he has the right kind of wood to work in; in some of the more carefully prepared work every pile has been inspected for checks before it was driven, and there have been wires at short intervals wrapped around it so as to prevent it splitting when driving. When as much pains as this are taken, and the same pains taken in creosoting, the best results are obtained.

Mr. Noble made one statement which I should like to ask a question about. He spoke of there being tall trees of the nature of palms. I suppose he means by that tall, rapid growing endogenous trees. Now, we have on our southern coast varieties of endogenous trees, the one most commonly known being called the cabbage palmetto, yet you can hardly call it timber, it is too pithy. Although the palmetto is very soft, it is harder than a cornstalk; though it is not very hard, it is full of little hard strings which, as the tree grows older, become larger, so that an old tall palmetto is comparatively hard. The palmetto is used for crib work on the sonthern coast as the one material which the teredo will never touch. It is driven lightly with a hammer, but it cannot be driven very far. It has occurred to me whether this timber Mr. Noble spoke of might not be valuable in harbors; whether, soft as they are, they might not be driven with a water jet in sand, and, even where not driven, they could not be used in crib work, and whether their softness and danger of crushing would

not be very much less than the danger from other sources. I remember a great many years ago an engineer of a Canadian Railroad reported that they excluded their best timber from ties; they refused to use cedar. The reason for it was that they wanted harder wood. He said that it was true if you were comparing cedar with the timbers they were using, it was not half as good the first year; it was, perhaps, a little more than half as good the second year; the third year it would be three-quarters as good, the fourth year it would be as good, and by-and-bye, long after the other timber had gone entirely, it would be about as good as the other timber was in the fifth year. Now, there is a great deal in that idea, and possibly these trees that Mr. Noble has spoken of might occupy a corresponding rank.

Mr. Noble: The timber I referred to is the maquengue palm; a maquengue palm a foot in diameter would have an exceedingly hard shell of perhaps three-quarters of an inch to an inch thick, and then the character changes very suddenly to pith. The outer timber is very strong and durable. I have never seen the palmetto in use, so I can not have an idea of the comparative merits of the two timbers. I should think that for crib work with no great weight, to keep the mud out of the excavations for embankments, that perhaps that timber might be used. There is almost any amount of timber there that can be used for very temporary purposes. I should think it quite likely the palm might resist the teredo, the fiber is so exceedingly hard and tough.

Mr. Morison: The teredo seems to object to a pith. He works in wood, but does not want an endogenous wood.

Mr. Noble: The teredo, I believe, does not attack the grain of some hard woods to any extent, the green heart, for example, partly, I understand, on account of its hardness, and if that is true, it is quite likely that some use could be made of the palm.

XXVI.

THE SOUTH WORKS OF THE ILLINOIS STEEL COMPANY.

By VICTOR WINDETT, Mem. W. S. E.

(Read February 16, 1898.)

The North Chicago Rolling Mill Company, operating steel and iron works on the North Side in Chicago, and in Milwaukee, under the stimulus of high prices and an eager market, in 1879 sought a location for new works. On account of the advantageous situation for receiving and shipping by lake and rail, land on the north banks of the Calumet river, at its mouth, was chosen. At that time, the river was navigable at the site for vessels of moderate draught, and rail communication was secured by connection to five railways. Four blast furnaces 21′ x 75′ were erected and blown in 1880. A Bessemer steel mill and rail mill followed in 1882. In the early part of 1889 the North Chicago Rolling Mill Company and the Union Steel Company united, and purchasing the plant of the Joliet Steel Company, formed the Illinois Steel Compay.

It was at once decided to enlarge the South Works. Four new blast furnaces with the attending yards and North Slip were built, the rail mill was torn out and rebuilt and the Bessemer mill remodeled. The former machinery was a 26″ 2 high train. This was torn out to give way to a 27″ 3 high mill with new engines. In addition, a new rail finishing building 150′ x 360′ was built. These changes it was expected would result in an output of 50,000 tons of ingots and 40,000 tons of rails per month. The original plat of ground was 74-½ acres of sand beach, and rising but little above the lake. This has grown (see Fig. 333) to about 260 acres, at an elevation of six and a half to sixteen feet above the lake, giving adequate drainage for fly-wheel pits and regenerator chambers and flues.

Today communication in the works is secured by the use of 36 miles of standard and 6½ miles 3′-0 gauge tracks. The standard gauge system is operated by the Chicago, Lake Shore & Eastern railway, of which the steel company is a stockholder. This railway operates other yards and trackage, giving communication with all railroads of Chicago, and over leased lines with the coal and limestone regions of Illinois and Indiana and the Joliet works of the company. The locomotives of the road vary in size and weight from eight wheelers of 230,000 pounds weight and 19″ × 26″ cylinders to four wheelers without trailing trucks of 16,000 pounds weight and 9″ × 16″ cylinders.

Marine shipments are handled at the docks of the South Slip, running into the plant from the Calumet river, and the North

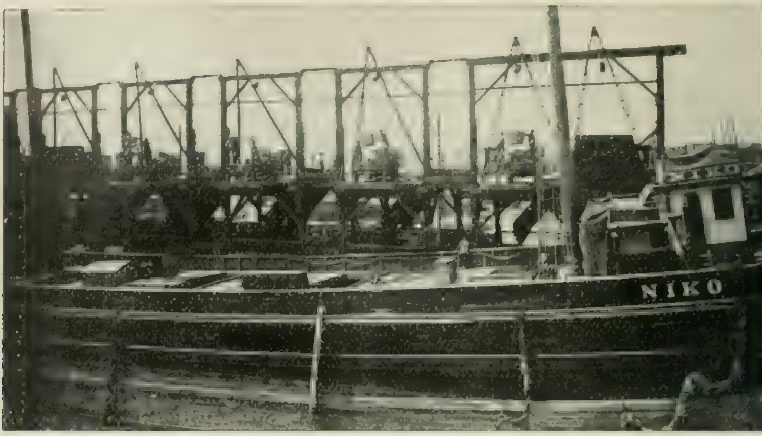


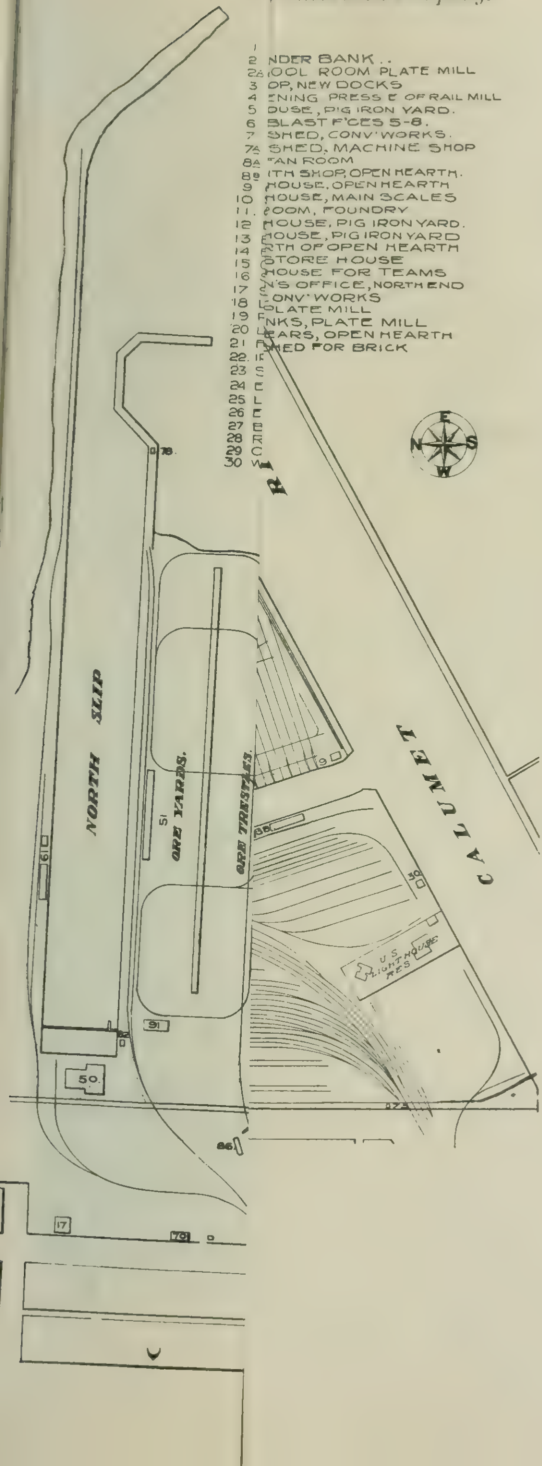
FIG. 334. South Slip. Unloading Ore Vessel.

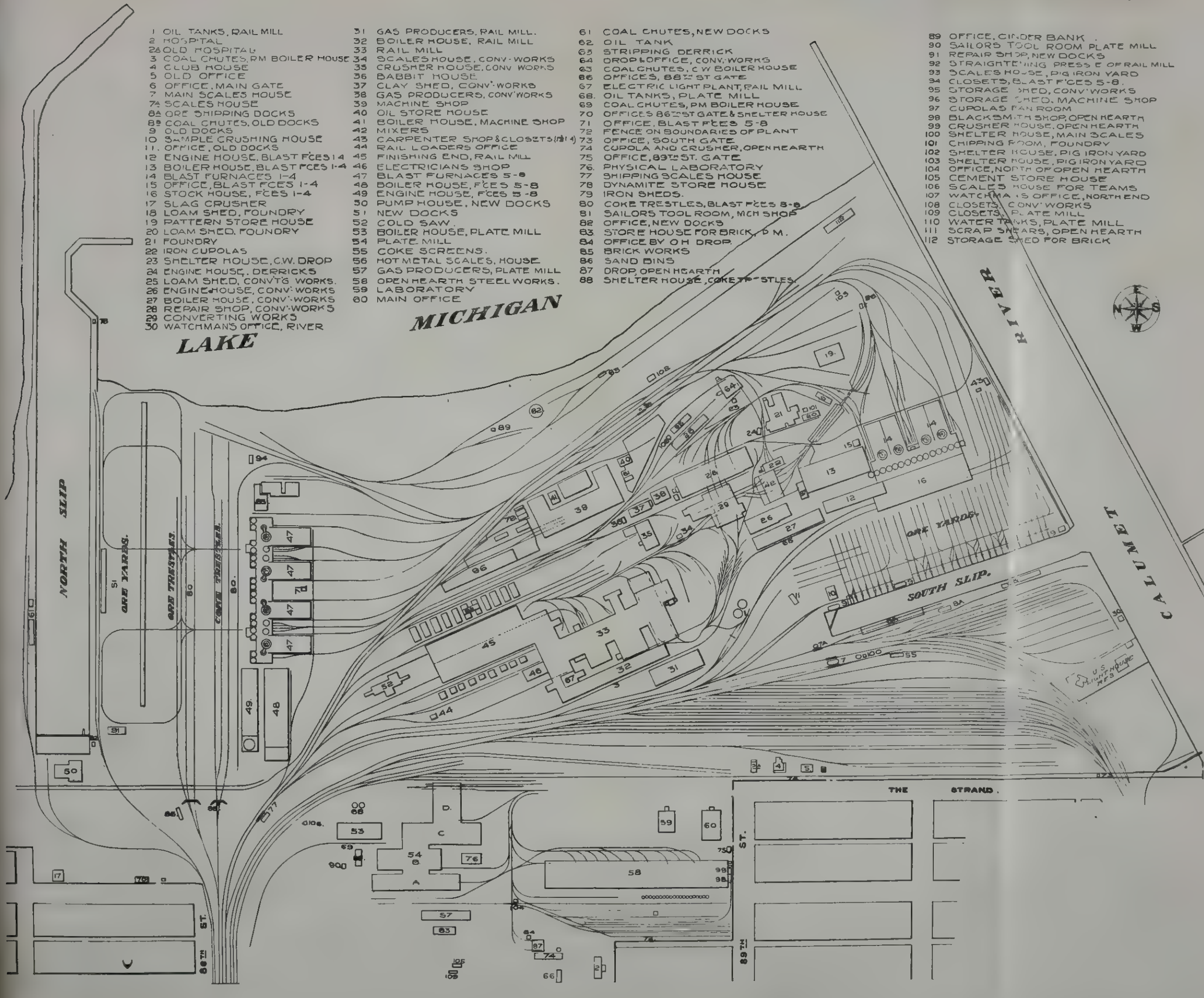
Slip opening into Lake Michigan with a protected entrance. The South Slip is 1,000 feet long and 96 feet wide. East of the South Slip are the ore yards for blast furnaces Nos. 1 to 4. Ore vessels are unloaded at the South Slip (Figs. 334 and 335) as follows: Buckets cylindrical in shape, 30″ diameter and 24″ high, holding 850 pounds of ore, hung below the center of gravity of the bucket by a bail and locked upright, when lifting, are placed in each hatch of a vessel. When filled, a bucket is hooked on to a pulley suspended from two swinging booms pivoted to the dock at the land ends and fastened together at the swinging end, where a sheave is placed over which the bucket rope runs. When a filled bucket in each vessel hatch is attached to the hoist, the hoist-engine man, on receiving a signal, starts the hoisting engine which is placed on the dock and the booms are simultaneously raised to a vertical position, while the bucket rope being partially hauled in at the same time brings the bucket up between the legs of the boom, where it is caught by two men standing on a platform 20 feet above the ground level. These men arrest the swing of the bucket, and on one pulling a latch, the bucket turns over and dumps in a hand push-car holding two tons. The empty buckets are then lowered into the hold of the vessel, detached, and another filled bucket is hooked on for a hoist. When the receiving car is filled, it is pushed on an elevated track to the desired portion of the ore yard and dumped with a sidewise motion. This method of handling requires men for each vessel hatch, as follows: Seven ore shovelers in the hold, two men on top to dump buckets, four car pushers. The buckets used are four and two push cars per hatch.

There are fifty-three of these hoists, so placed that three of the largest size of vessels or four small ones may be unloaded at the same time. When discharging into cars standing on the dock, a

IG. 333.

llinois Steel Company.




1 OIL TANKS, RAIL MILL
2 HOSPITAL
2a OLD HOSPITAL
3 COAL CHUTES, P.M. BOILER HOUSE
4 CLUB HOUSE
5 OLD OFFICE
6 OFFICE, MAIN GATE
7 MAIN SCALES HOUSE
7A SCALES HOUSE
8A ORE SHIPPING DOCKS
8B COAL CHUTES, OLD DOCKS
9 OLD DOCKS
10 SAMPLE CRUSHING HOUSE
11 OFFICE, OLD DOCKS
12 ENGINE HOUSE, BLAST FCES 1-4
13 BOILER HOUSE, BLAST FCES 1-4
14 BLAST FURNACES 1-4
15 OFFICE, BLAST FCES 1-4
16 STOCK HOUSE, FCES 1-4
17 SLAG CRUSHER
18 LOAM SHED, FOUNDRY
19 PATTERN STORE HOUSE
20 LOAM SHED, FOUNDRY
21 FOUNDRY
22 IRON CUPOLAS
23 SHELTER HOUSE, C.W. DROP
24 ENGINE HOUSE, DERRICKS
25 LOAM SHED, CONV'G WORKS.
26 ENGINE HOUSE, CONV' WORKS
27 BOILER HOUSE, CONV' WORKS
28 REPAIR SHOP, CONV' WORKS
29 CONVERTING WORKS
30 WATCHMAN'S OFFICE, RIVER
31 GAS PRODUCERS, RAIL MILL.
32 BOILER HOUSE, RAIL MILL
33 RAIL MILL
34 SCALES HOUSE, CONV-WORKS
35 CRUSHER HOUSE, CONV WORKS
36 BABBIT HOUSE
37 CLAY SHED, CONV' WORKS
38 GAS PRODUCERS, CONV' WORKS
39 MACHINE SHOP
40 OIL STORE HOUSE
41 BOILER HOUSE, MACHINE SHOP
42 MIXERS
43 CARPENTER SHOP & CLOSETS
44 RAIL LOADERS OFFICE
45 FINISHING END, RAIL MILL
46 ELECTRICIANS SHOP
47 BLAST FURNACES 5-8
48 BOILER HOUSE, FCES 5-8
49 ENGINE HOUSE, FCES 5-8
50 PUMP HOUSE, NEW DOCKS
51 NEW DOCKS
52 COLD SAW.
53 BOILER HOUSE, PLATE MILL
54 PLATE MILL
55 COKE SCREENS.
56 HOT METAL SCALES, HOUSE
57 GAS PRODUCERS, PLATE MILL
58 OPEN HEARTH STEEL WORKS.
59 LABORATORY
60 MAIN OFFICE
61 COAL CHUTES, NEW DOCKS
62 OIL TANK
63 STRIPPING DERRICK
64 DROP & OFFICE, CONV. WORKS
65 COAL CHUTES, C.W. BOILER HOUSE
66 OFFICES, 88TH ST GATE
67 ELECTRIC LIGHT PLANT, RAIL MILL
68 OIL TANKS, PLATE MILL
69 COAL CHUTES, P.M. BOILER HOUSE
70 OFFICES 86TH ST GATE & SHELTER HOUSE
71 OFFICE, BLAST FCES 5-8
72 FENCE ON BOUNDARIES OF PLANT
73 OFFICE, SOUTH GATE
74 CUPOLA AND CRUSHER, OPEN HEARTH
75 OFFICE, 89TH ST. GATE
76 PHYSICAL LABORATORY
77 SHIPPING SCALES HOUSE
78 DYNAMITE STORE HOUSE
79 IRON SHEDS.
80 COKE TRESTLES, BLAST FCES 5-8
81 SAILORS TOOL ROOM, MCH SHOP
82 OFFICE, NEW DOCKS
83 STORE HOUSE FOR BRICK, P.M.
84 OFFICE BY O H DROP
85 BRICK WORKS
86 SAND BINS
87 DROP, OPEN HEARTH
88 SHELTER HOUSE, COKE TRESTLES.
89 OFFICE, CINDER BANK
90 SAILORS TOOL ROOM PLATE MILL
91 REPAIR SHOP, NEW DOCKS
92 STRAIGHTENING PRESS E OF RAIL MILL
93 SCALES HOUSE, PIG IRON YARD
94 CLOSETS, BLAST FCES 5-8.
95 STORAGE SHED, CONV' WORKS
96 STORAGE SHED, MACHINE SHOP
97 CUPOLAS FAN ROOM
98 BLACKSMITH SHOP, OPEN HEARTH
99 CRUSHER HOUSE, OPEN HEARTH
100 SHELTER HOUSE, MAIN SCALES
101 CHIPPING ROOM, FOUNDRY
102 SHELTER HOUSE, PIG IRON YARD
103 SHELTER HOUSE, PIG IRON YARD
104 OFFICE, NORTH OF OPEN HEARTH
105 CEMENT STORE HOUSE
106 SCALES HOUSE FOR TEAMS
107 WATCHMAN'S OFFICE, NORTH END
108 CLOSETS, CONV' WORKS
109 CLOSETS, PLATE MILL
110 WATER TANKS, PLATE MILL
111 SCRAP SHEARS, OPEN HEARTH
112 STORAGE SHED FOR BRICK
LAKE MICHIGAN
NORTH SLIP
ORE YARDS
ORE TRESTLES
COKE TRESTLES
ORE YARDS
SOUTH SLIP
CALUMET RIVER
THE STRAND
88TH ST.
89TH ST.

trap door is opened on the receiving platform for each boom, which permits the buckets to be emptied direct into chutes leading to the cars.

While three or four vessels are discharging ore at this slip, room is provided so that another may be unloading lumber while another is receiving coal from chutes in preparation for a voyage.

The ore yards reached by this slip have a storage capacity of 300,000 tons of ore.

The dockage on the Calumet river extends 2,500 feet, but such is the capacity of the slips that this has not been made use of so far in shipping. Along Lake Michigan, the property stretches to the northward for 5,200 feet. Three thousand feet north of the river mouth is the North slip, entered from the lake, through a protected mouth opening to the southeast and contracting to a throat of 100 feet width to keep out heavy seas from the interior of the slip. This harbor is 200 feet wide and 2,900 feet long. Ore is received here for blast furnaces 5, 6, 7 and 8 and stocked in yards of 700,000 tons capacity lying between the slip and furnaces. Facilities are also provided for loading from vessel to cars direct, for ore destined for other plants of the company. Thus room is had in which to store sufficient ore for use during the winter time when navigation is impossible.

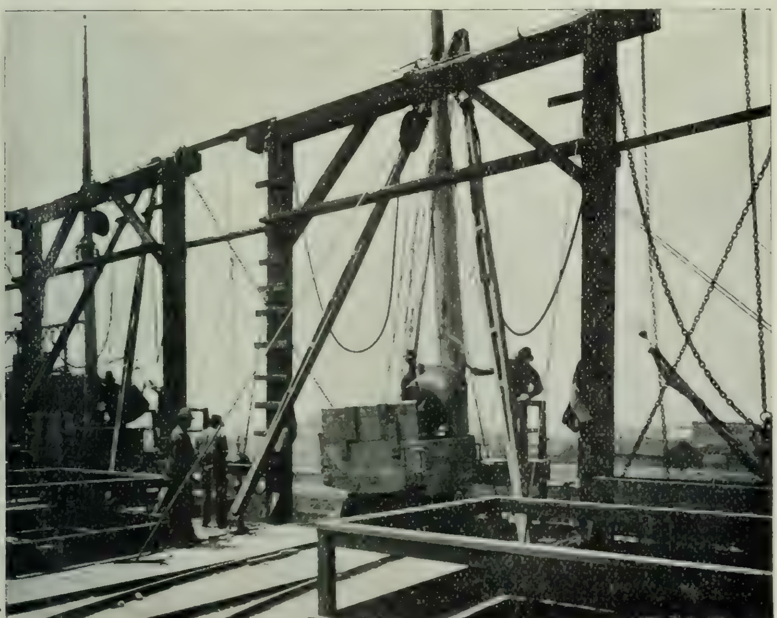


FIG. 335. South Slip. Unloading Ore Vessel.

FIG. 336. North Slip. Unloading Ore Vessel by Brown Hoist.

At the North Slip, ore is unloaded by the Brown Hoist Conveying Co's. Cleveland machines, of which there are sixteen in use, shown in Figs. 336 and 337. The buckets in use, are larger than those of the South Slip and of shape more like a scoop, and hold one ton. These hoists are so well known from their use on the Chicago Drainage canal and at the Lake Erie ports that an extended description here is not needed. With the present equipment eight vessels can receive and discharge cargoes sim

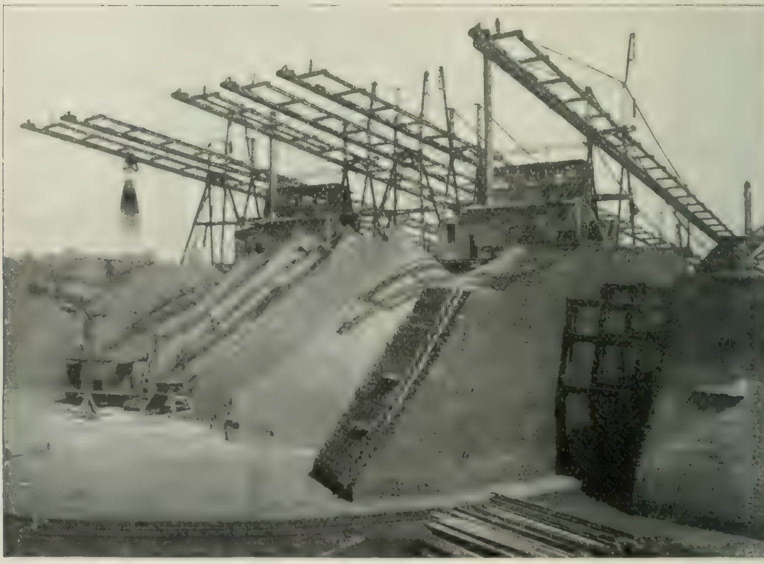


FIG. 337. North Slip. Discharge of Ore Bucket of Brown Hoist Steam Shovel for Loading Ore into Charging Buggies.

ultaneously at this slip. Shipments are made here of all the company's product destined for water shipment to points in Canada and the United States on the great lakes or to foreign countries. In this way as well as by rail, quick handling for export and domestic trade is secured for steel rails, billets, rods, wire, cotton ties, barrel hoops, tinplate bar, track supplies, pig iron, Portland cement and other of the company's products. A striking example of rapid handling of ore is that done by a gang of 42 men, including signal boys, who unloaded a cargo of 1,600 tons from a vessel in the morning of a day, and after lunch unloaded another vessel carrying 1,750 tons or 3,350 tons in twelve hours. This was done at the South Slip. The average cargo will run about 2,800 tons, as in the latter part of the year vessels are loaded less with ore than in the summer, and there are some of the smaller class of boats which in the course of a season make many trips, and consequently bring down the average of the cargoes.

Following is a table giving figures of vessels, etc.:

Date	1895	1896	1895	1897	1897	1897
Vessel	Manhattan	G. N. Orr	Manchester	"137"	Polynesia	Crescent City
Cargo. tons	2,008	2,639	2,750	4,000	5,293	5,293
Men & boys	44	81	95	158	143	169
No. boat hatches	4	9	7	12	12	12
Time in hours unloading	10	6¼	6⅓	8½	10¾	10
Tons per hour	201	422	435	471	491	529
Tons per man per hour	4.6	5.2	4.6	3.0	3.4	3.1
Slip	North	North	South	South	North	South

Season opens about April 15th, closes about December 15th.

Maximum cargo in 1897, "Amazon," 5.575 tons.

Total ore received in 1897, 1,629,865 tons.

FIG. 338. Blast Furnace 1–4.

BLAST FURNACES.

Lying east of the South Slip is the plant of blast furnaces Nos. 1,2,3,4, shown in Fig. 338. These furnaces were built in 1880. The stacks are 75 feet in height and built with a bosh diameter of 19′-0. Each furnace is provided with four hot blast Whitwell-Foote brick stoves, 67 feet high and 21 feet in diameter. Steam is furnished at 100 pounds pressure by 40 horizontal tubular boilers, 72″x 20′-0, fired with waste blast furnace gas. Air is delivered to the furnaces by 10 vertical blowing engines made by the Cuyahoga Falls Engine Co., of Cleveland. Two engines are used for each furnace regularly, and there are two spare engines so piped as to be available in lieu of any of the others. A stock house 360 feet long and one hundred feet wide shelters the daily coke supply and gives access to the hoist towers, of which there are two, each reaching by a bridge two of the furnaces.

FIG. 339. Blast Furnace 5-8.

Situated south of the North Slip is the plant of the Blast Furnaces Nos. 5 to 8, shown in Figs. 339 and 340, which was built in 1890. These furnaces are 85 feet high with a 20 foot bosh circle, and are furnished with four Massick & Crooke hot blast stoves 70 feet high and 22 feet in diameter. Each stove has its own waste gas chimney instead of all using a single stack as at the South Furnaces.

Forty-eight 72″ x 20′ boilers give steam raised by waste gas combustion to drive two blowing engines for each furnace. The ten blowing engines are operated condensing and are of the Southwark Foundry & Machine Co.'s manufacture. The air cylinders of two of these engines are fitted with positive motion gridiron valves, fitted to the heads of the cylinder, and others are to be similarly equipped.

Coke and limestone for the furnaces are unloaded from the cars on trestles about 22 feet high running parallel to the line of the furnace plant, and situated so as to require but a short haul from the pile to the hoist towers. Bins under the trestles are built to receive the coke from the cars, and while loading the hand bug-

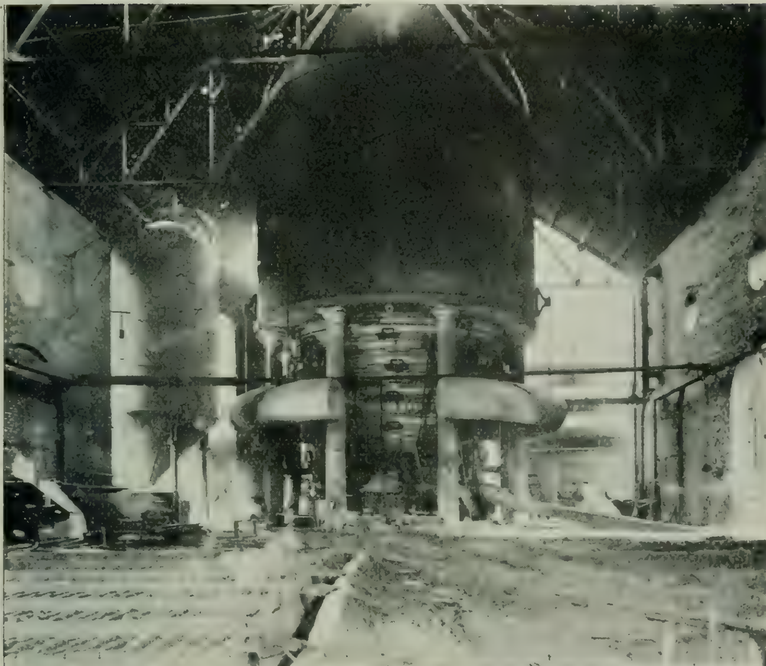


FIG. 340. Interior of Cast-House. Lower part of No. 5 Blast Furnace.

gies, the coke passes over a grating which screens out the dust. Ore is loaded into hand buggies by manual labor, and also by a steam shovel which takes at one scoop ore sufficient for a buggy. The buggies are collected and delivered to the furnace by a narrow gauge road, as the haul by men would involve considerable labor. Each blast furnace is supplied with a hoist tower in which are two cages operated by an 8″ x 10″ Crane hoisting engine.

The flue dust carried over by the waste gases is caught before passing into and choking up the passages of the stoves. This dust consists of powdered ore with a little coke and limestone dust. This is moulded into briquettes, cohesive strength being imparted by a slight admixture of lime and baked in an atmosphere of exhaust steam and hot waste gases from a boiler firebox. An excellent quality of building brick of great density and strength has been made by a similar mode of treatment of blast furnace slag. Such bricks have a smooth face, are light gray in color and make a handsome facing for buildings. The blast furnace slag is run from the furnace into Weimer slag cars, which are emptied into long beds, the slag spreading out into a thin layer, two to three inches thick. When a sufficiently large amount of slag is accumulated, it is excavated and loaded into gondola cars at the rate of 10 cars per hour by a Bucyrus steam

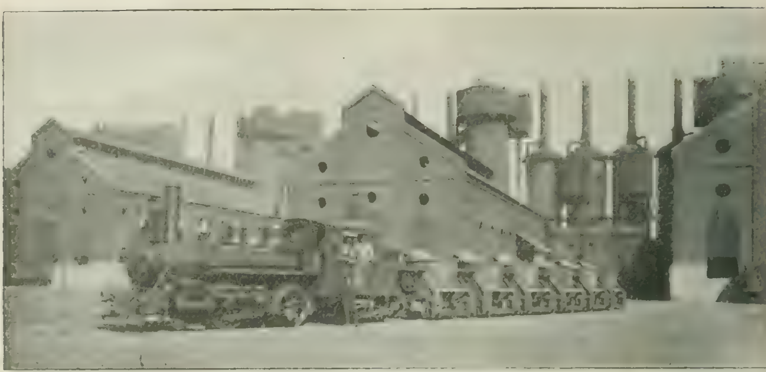


FIG. 341. Ladles carrying 75 tons molten iron from Blast Furnace to Mixer.

shovel, and is then used in street making concreting and railroad ballasting. Used in concrete, a strong product results on account of its properties acting like a hydraulic cement. Another product of the blast furnace department is mineral wool, made by spraying with a steam jet melted blast furnace slag.

Iron is ordinarily cast from the furnace into 12 ton ladles, shown n Fig. 341, and taken while liquid to the Bessemer or Open Hearth Steel plants. The Sunday iron is run into pigs. This latter product is then used in the Bessemer Works Cupolas, Open Hearth Furnaces or shipped away.

When all eight furnaces are in operation, the product is 80,000 tons of iron a month, or 960,000 tons per year. No. 1 furnace ordinarily produces; spiegel iron, when its product is 7,000 per month.

THE BESSEMER STEEL MILL.

Ground was broken for the Bessemer Converting Works in 1881. Metallurgical operations began in 1882. In 1890 the converters were increased in size and changed from the early design where the top of the vessel was brought over as a hood, making the opening very eccentric to a concentric nose and increasing the size so as to admit of 14-ton heats instead of 10-ton heats. The old Holley hydraulic cranes of five-ton capacity, lifting a single mould or ingot at a time, have given way to Wellman steam and hydraulic cranes, modified to lift two ingots or moulds at once, and these are to be replaced by 15-ton cranes of the same general type with three sets of tongs, so that instead of 18 lifts per heat, there will be but six such operations in handling the moulds and ingots for the same weight of product. The benefit of this reduction will be felt in a gratifying increase in output, and solves the question of handling a large output, which in some mills is answered by casting on cars.

Iron is run from the blast furnaces into ladles of 12 tons capacity (Fig. 341) and conveyed to the "mixers" (Fig. 342). These are horizontal cylindrical vessels holding 150 tons each of iron. The

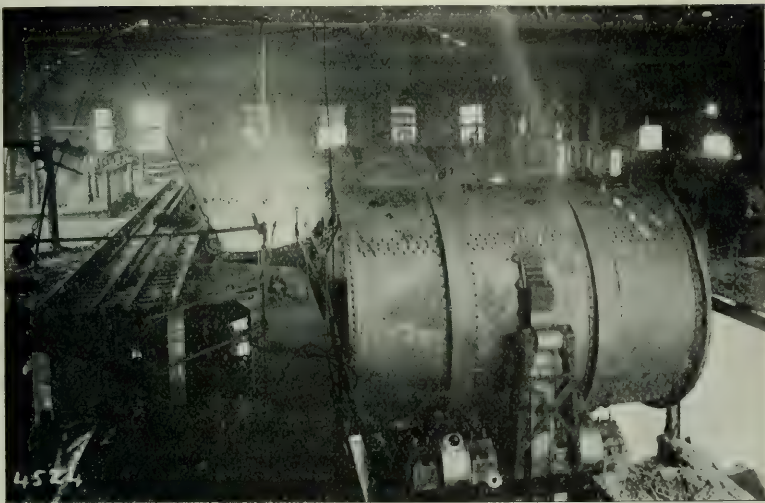


FIG. 342. Mixers of Bessemer Converting Works.

ladles are elevated to the receiving floor of the mixer building by a hydraulic lift revolving through 90 degrees in the ascent to bring the spout of the ladle into the pouring position. The turning down and up of the ladle is done by power applied through an adjustable socket, which is thrown into gear with the mechanism of the ladle and then disengaged.

The ladle is moved over the charging floor by a cable railway, and descends on another lift, which, while going down, is turned into position to run the ladle on the surface track. A spout is placed on the side of each of the mixers, from which metal is poured into a ladle standing on scales by revolving the mixers. The mixers stand on four heavy rollers and power is applied by a rack attached to the plunger of a hydraulic cylinder and gearing, with teeth placed on the periphery of the mixer. Immediately after the iron has run into the ladles at the blast furnaces, the foreman at that plant telephones to the clerk of the mixers the estimated percentage of silicon and sulphur of the iron. This is used to calculate the composition of the mixer metal. This calculation is repeated as soon as the true analysis is received from the laboratory. In this way, the variation of the calculated and actual analysis will not exceed 0.1 per cent silicon or 0.05 per cent sulphur.

As the iron enters the Bessemer mill, the steel blower receives a ticket, giving the weight and composition of the metal, and is thereby guided in his blowing of the metal. The calculation of the composition of the metal in the mixers is performed by a chart and decimal scale on the principle of proportional triangles, which is as satisfactory as a slide rule in rapidity and ease of working.

An elevated track runs in front of the three converters and at such an elevation as to allow pouring iron from the mixer ladle to the converter. This ladle is emptied and brought back to a vertical position by power. Spiegel iron for recarburizing is melted from the pigs in cupolas, or a mixer supplied from a blast furnace with hot metal is used. This latter method is superior in cheapness and uniformity of chemical composition. After recarburizing in the converter, the resulting steel is poured into a receiving ladle, and from this into the casting ladle. This double pouring process secures perfect mixing, and hence uniformity of steel.

The casting pit is circular, about 250° being available for ingot casting, and the remainder for ladle handling and cleaning.

Another casting pit in the rear of the ladle repair shop is used for soft Bessemer steel ingots, of which some of the commoner grades of plates are made.

Following are figures of output of the mill for periods named:

Date.	Period of Operation.	Tonnage of Ingots.
	12 hours	1,288.5
	24 hours	2,555.6
Week ending Nov. 22, 1896	132 hours	12,739.1
Month December, 1897	49½ turns of 12 hrs.	54,176.
Year	536 turns	520,245.

The capacity of the mill is about 625,000 tons of steel ingots per year.

The moulds are stripped from the ingots as soon as they have solidified sufficiently to bear handling, and are placed on a car by the crane and removed by a narrow gauge locomotive to the mouldyard to cool.

RAIL MILL.

The ingots are put into cast iron cars holding four ingots each, and taken to the rail mill, where they are placed in soaking pits to solidify and attain a uniform temperature. The soaking pits are rectangular in form and accommodate 12 ingots each. The pits are heated by petroleum, the air used in combustion passing through regenerators which have been heated by the waste gases leaving the pits. They are placed in two parallel lines with a cable operated tilting transfer car running on a track between, leading to the ingot run of the blooming mill.

Four of the pits are served by two overhead traveling electric cranes. These cranes have a cross traveler on the main girders, which, with a hoisting bar, gives access to all below. These cranes are 78 feet span, 25 tons capacity, move 300 feet horizontally and 100 feet vertically per minute. The other pits are served by four cranes similar to those of the Bessemer mill, though handling but one ingot at a time. It is intended to remove these latter cranes, using the travelers to handle all work here.

The ingot is reduced in the blooming mill (Fig. 343) from 16¾" square to an 8" bloom and about 24 feet long. This mill was

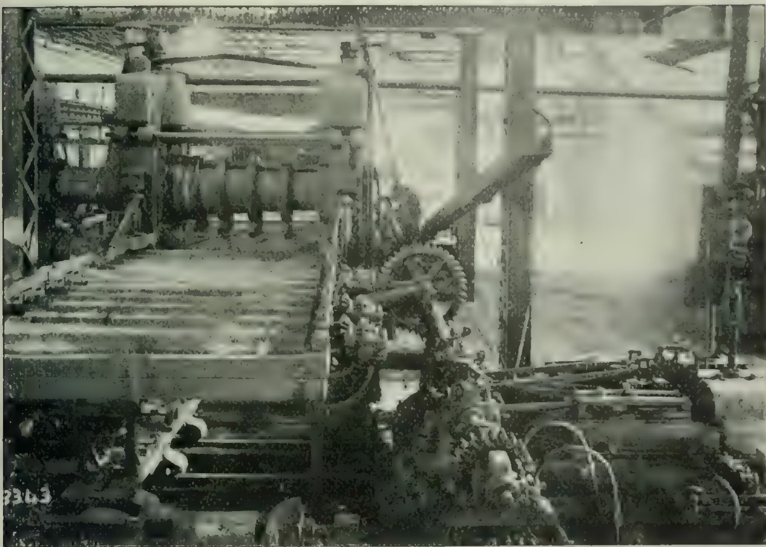


FIG. 343. Rail Mill. Blooming Rolls and Tables.

built in 1882 and since then has been almost entirely rebuilt. The rolls are 40″ in diameter and are 3 high. On leaving the blooming rolls, the drawn-out ingot is on its way to the roughing rolls (Fig.344), cut into three blooms and the ends cropped off. These latter drop below the floor level to a traveling conveyor, which takes the crop ends outside and drops them on to scrap cars and they are returned while hot to the Bessemer Works to be worked over. Between the bloom shears and first roughing tables is a tilting table, which when necessary, by a stopping of the rail

FIG. 344. Rail Mill. 2nd Roughing Rolls and Tables.

mill, transfers the blooms by means of a "telegraph" conveyor to a reheating furnace. This furnace is useful also to receive blooms when the blooming rolls are rolling too fast for the rest of the mill, and to serve them out again at such times as required should the rest of the mill run faster than the blooming mill. The blooming rolls are driven by a Porter-Allen 44 × 66 engine of 1,600 H. P.

The first roughing and finishing rolls are driven by an engine of the same make 54 × 66, of 2,800 H. P., running at 72 revolutions.

Beyond these rolls are the second roughing rolls, driven by an engine similar to the blooming engine, developing 1,700 H. P. These engines all have 25 feet 55 ton fly-wheels.

The steel is not handled by hand tools at all, all transferring from one set of rolls to another being accomplished by means of power driven tables, and when necessary the bar is turned over on one side or upside down for the next pass by power applied simultaneously with the movement of the tables. Owing to the shape of the building, which was erected in 1882 for a 26″—2 high rail train, the present 27″—3 high mill, designed in 1889 by R. Forsyth, is in two parts placed tandem with the blooming mill. The ingot is reduced by 9 passes in the blooming rolls, 5 passes in the first roughing rolls, 4 passes in the second roughing rolls and dummy rolls, and 4 passes in the finishing rolls (Fig. 345), making 13 passes from the bloom to rails, or 22 passes in all. After being sawed hot to length desired by saws running at 1,500 revolutions per minute, the rails are cooled on a large, well aired hot bed. When cold, they are mechanically loaded on a transfer car drawn by a narrow gauge locomotive on a track running the length and in the center of the finishing building. On reaching the empty skids in this building, the engine driver unloads the car by admitting steam from the locomotive into two cylinders in the car, which lifts the beams of the car supporting the rails, and they slide off the car on to the straightening skids.

After straightening, drilling and passing a severe double inspection by men of the company and inspectors representing the purchaser, the rails are loaded, weighed and shipped out to the buyer in three hours from the time the crude metal ran out of the blast furnace, it is loaded ready for shipment as a rail. All rails made during the night are inspected in daylight.

Another feature of the rail mill is the excellent arrangement for rolling billets of various sizes. Extra passes for this purpose are provided in every set of first and second roughing rolls, and movable tumblers are placed so that a bloom may be directed either in the rail passes or the billet passes. Beyond these rolls and then tables lies the runway for billets to a duplex horizontal hydraulic shear, by which billets are cut to ordered size. From the shear the billets are carried on a surface conveyor outside of the building to an elevated conveyor running over the billet dock, and are dropped off by means of a switch to the

desired pile. The horizontal conveyors consist of a chain of side links riveted on a pin on which revolves a roller. On this roller the billet moves at double the speed of the conveyor. By means of this equipment, any portion of the product of the mill may be made in the shape of billets at any desired time for, no roll change being necessary, the only requirement being to signal to the leverman of the roughing rolls to put the bloom into a rail pass or a billet pass. The facilities for making this form of product has permitted the making of 900 tons of 3⅞ inch square billets in twelve hours. It is not an unusual thing to see one bloom rolled into 3⅞ inch billets and the following one rolled into rails which will be sawed and delivered on the hot bed before the bar has been entirely sheared into billets.

There is no other mill in the country that has this arrangement for billet making, and it is of great advantage to the South Works, since it is thereby enabled to fill orders for billets of any carbon and in any quantity without interference with the production by loss of time due to changing rolls.

The weight of rails rolled runs from 30 to 100 pounds per yard, and length up to 60′–0. Rails of heavier weights and greater lengths can be rolled as desired. Following are some of the records of the mill for output:

Date.	Time.		Wt. of rail per yard.	No. of rails.	Wt. of rails.	Wt. of billets.	Total wt.
Nov. 1, '94	12 hrs.		30	4,314			
Oct. 23, '97	12 "		60	3,898			
Oct. 20,	12 "	day turn	80		1,152	96	1,248
	12 "	night turn	80		1,121	39	1,160
Nov. 1, '94	24 "		30 / 48 / 56–60	7,624		(including roll change)	
Feb. 25, '96	24 "		70	6,723		2 " "	"
Sept. 28, '97	24 "				2,108		2,108
Oct. 20, '97	24 "		80		2,273	135	2,408
Sept. 3—	132 "		Standard				
Oct. 5, '95	week		Sections	30,354			
Mar. '96	"		Light Sec.	3,102			
Oct. '95	"						10,134
Aug. 15–21, '97	"						10,717
Oct. 18–23, 97	"						11,322
Mar. '96	Month			125,265			
Aug. '97	"						43,710
Dec. '97	"						47,259
1897	Year		534 turns	1,290,105	407,002	37,903	444,905

The capacity of the mill for a full year of 568 12-hour turns is well over 5,000,000 tons of finished rails.

The output of heavy rails for one turn of twelve hours on medium weight rails was sufficient to lay 21½ miles of track, while that of the year 1897 would stretch from Eastport, Me., to Seattle, Wash., a distance of over 3,660 miles.

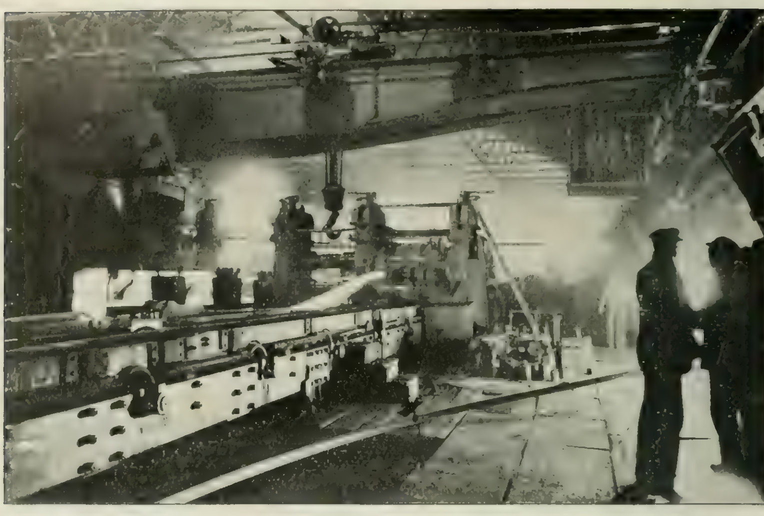


FIG. 345. Rail Mill.—Finishing Rolls and Table, with Rail being Rolled.

THE OPEN HEARTH STEEL DEPARTMENT.

The Open Hearth Steel Department was put in operation in February, 1895. The building containing the furnaces and casting pits is of brick and steel construction 100 feet wide and 651 feet long.

The furnaces, ten in number, are placed in a row along the length of the building, giving the east half of the building for pit work.

Back or west of the furnaces is a charging floor twelve feet above the yard level. Below the charging floor and on independent foundations from those of the furnaces are the Siemens regenerators and the gas and air ducts and valves. The charging floor and furnaces are spanned by a 20-ton electric traveling crane of nearly fifty feet span. Working over the front of the furnaces and pits are one 40-ton, two 30-ton and two 75-ton electric traveling cranes, running up and down the length of the building. There are also three Wellman electric charging machines serving the furnaces. There are four open hearth steel furnaces of 25-28 tons capacity of the Wellman stationary style of the Siemens Regenerative furnaces, and two 25 and four 60 ton furnaces of the Wellman rolling style, one of which is shown in Figs. 346 and 347. The annual output of these ten furnaces is 175,000 tons of ingots and castings.

Stock for charging the furnaces is loaded at the mills or stock piles in steel boxes on narrow gauge cars and carried up an incline to the charging floor and placed at the back of the furnaces to be charged.

The boxes are picked up, thrust into the furnaces, emptied and

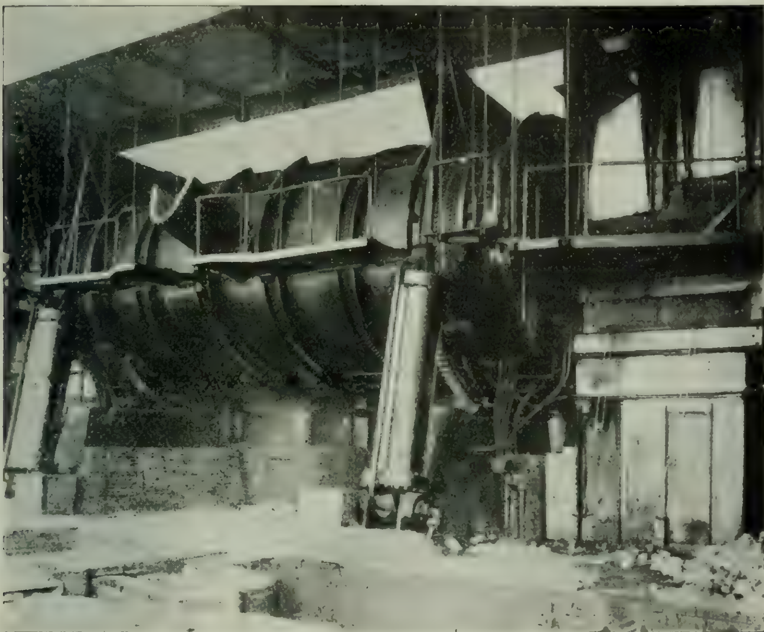


FIG. 346. 75-Ton Rolling Open Hearth Furnace—Front.

replaced on the car by the charging machine. All doors and gas valves are operated by pneumatic cylinders, the operating cocks of which are worked by boys. The melted steel is tapped into ladles of 30 to 75 tons capacity, while suspended from a traveling crane, and are taken immediately to a pit full of moulds. A steel lined casting pit 30 feet deep and of large diameter permits the casting of ingots of great size, and of weight up to 150 tons each. The making of small and intricate castings is quite as carefully attended to as those of greater size.

Instead of running a charge on ,pig iron and steel scrap, hot metal direct from the blast furnaces may be used to displace the pig iron which otherwise would be used. This operates to reduce the time per heat and the loss of charge by oxidation as well as the fuel used. A large plant of bituminous coal gas producers stands close at hand, so that coal gas may be used if desired instead of petroleum.

The rolling furnaces have the advantage over the stationary ones, in that during the working of the furnace the tapping hole is removed from the metal and therefore does not need so strong a stopping up, and there are advantages in repairing the lining after a heat. In two of these types of furnaces, the gas and air ports are detached from the furnace, decreasing to a large extent the weight of the moving parts and permitting the replacing of

FIG. 347. 75-Ton Rolling Open Hearth Furnace.

the old ports by new ones without a serious delay in the operation of the furnace.

PLATE MILL.

The Plate Mill was erected at the same time as the Open Hearth department. There are five reheating furnaces for ingots. One of them, called the preheating furnace, is so built that iron cars whose tops are covered with sand are run in the furnace. The track at each end is so pitched as to cause the overhanging sides of the cars to form a water seal, so as not to have an inrush of cold air. Ingots are heated to a cherry red, and then the cars are carried along on the track of the preheater to the reheating furnaces, in which, when placed there, the ingots are heated to a rolling temperature. From the furnaces, the ingots are carried to the tables of the rolls by a Wellman electric hydraulic charging car, of which there are two in use here. A 90″ and a 132″ plate train, both 3 high, are used in rolling. These trains are shown in Fig 348. These are driven by a 3,000 H.P. Porter-Allen engine. The intermediate roll is not connected by gearing to the engine as are the others, but is raised up or down in its bearings to roll a plate either with the top or bottom roll. The tables on each side of the rolls are pivoted at the end away from the rolls and lift by hydraulic pressure to accommodate the position of the plate being rolled when in the upper or lower pass. The plates are finished at a dull heat and pass directly to the straightening rolls. From the hot bed, the plates are carried to the marking beds, where the large plate is marked to ordered sizes, and thence to the shear tables by electro-magnetic hoists shown in Fig. 349. In the shear room, electric magnets pendant from traveling cranes are used in handling all plates. Finished plates

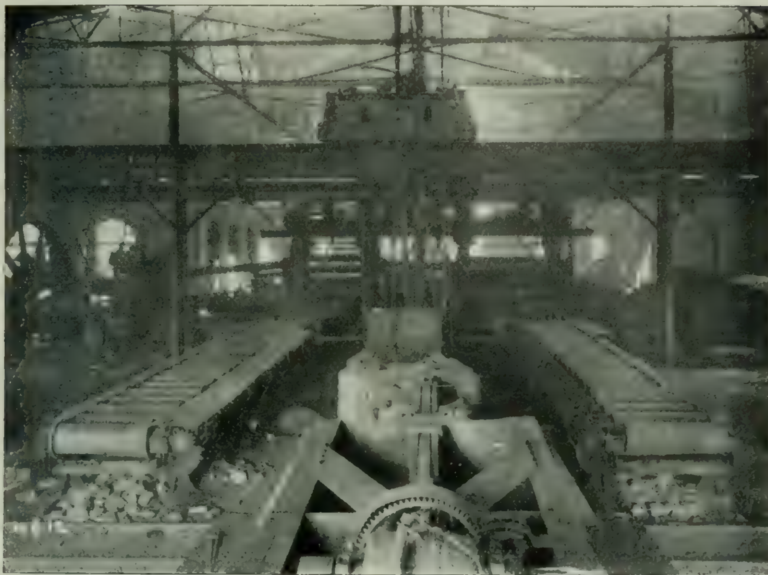


FIG. 348. Plate Mill. 90" and 132" Trains.

are rolled from 3-16" to 1½" up to 126" in width and 60 feet long.

The capacity of the plate mill is 84,000 tons of finished plates per year. Much of the machinery in these two departments is electrically driven. One of the shears is a rotary machine in which the blades are two steel discs on stationary shafts, while the plate being clamped in its center is revolved, cutting out true circles.

THE MECHANICAL DEPARTMENT.

The South Works is a self-contained plant. By means of a machine shop 300 feet long and 150 feet wide, an iron foundry, a steel foundry, blacksmith, carpenter and pattern shops of sufficient size, all repairs to machinery are made without delay, new machinery built and new construction or extension of the plant undertaken All of the ingot moulds used are made in the iron foundry, which has been very successful in securing long service for its moulds.

Steam is generated in over two hundred boilers, not including those of locomotives. These boilers are mainly 6 feet in diameter, 20 feet long with 50 4½" tubes set horizontally in pairs, each pair having a large iron stack. Power is obtained by the expansion of the steam used in engines and pumps, of over 25,000 horse-power, using over 350 steam cylinders.

Blast furnaces 1 to 4, the Bessemer converting works and rail mill have supply water pipes leading from the South Slip to their

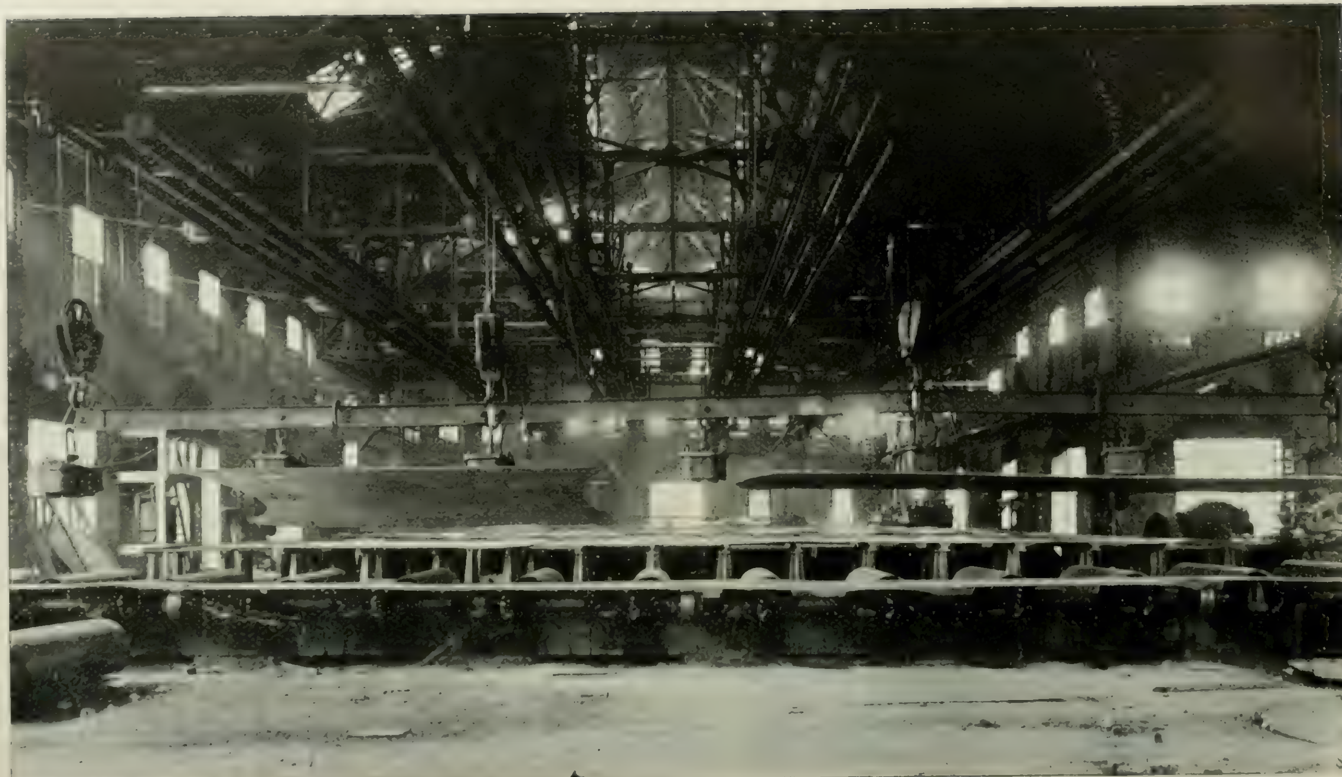


FIG. 310. Plate Mill. Electro-Magnetic Conveyors taking a Plate from the Marking Platform to the Shears.

respective pumping plants. At the west end of the North Slip is a pumping station comprising four 6′ × 20′ boilers in the boiler house, delivering steam to the engine house, in which are three engines. These are compound, condensing, high speed Porter-Allen engines, coupled directly each to a Southwark Foundry & Machine Company's centrifugal pump. Water is lifted 10 feet from the lake and forced 8 feet, being delivered to a 40-foot tank through a 48″ pipe. From here it is distributed by compound Worthington pumps to the blast furnaces 5 to 8, Plate Mill, Open Hearth and C. L. S. & E. Ry. Shops. The centrifugal pumps are rated at 1,000,000 gallons of water per hour each. There is room for a fourth pump in the station when needed.

LABORATORIES.

Much care is exercised in securing the use in the various departments of the best materials. Chemical analyses are constantly being made of all raw materials used, of ore, coal, coke, oils, pig iron, ingots, rails, billets, plates, limestones, etc. Precision of work is aimed at and secured, as shown by favorable results obtained when brought into competition with trained chemists of other establishments. An idea of the dependence of the plant on its corps of chemists is shown by the fact that over 140,000 chemical analyses were made in 1896.

A branch of investigation but slightly followed in this country, and but by few in Europe, is the study of the microstructure and crystallography of steel and kindred forms of iron in all of the stages of manufacture. An investigation of this kind has been carried on at the South Works and developed to a high degree by original investigation in this nearly unexplored field of science by the aid of the best obtainable instruments and methods. It is possible by such investigation to determine the chemical composition of iron and steel independently of the chemist, and to discover the heat treatment and comparative rolling temperature of the piece studied, and in that way regulate the reheating treatment. This work was begun by A. Sauveur, whose memoirs on the subject in the transactions of the A. I. M. E. are based on the work done here.

A well-equipped physical laboratory adjoins the plate mill, where all steel is tested before shipment. In this way, the strictest requirements of the buyer as to physical and chemical characteristics of material can be faithfully fulfilled.

THE HOSPITAL.

A notable feature of this plant is the hospital service given by the company, free to the injured employes. The Hospital building was completed in 1896, being built with all the requirements of modern surgery. The building is 116 feet x 28 feet, of pressed brick and brown stone trimmings. It is two stories and basement high. In the basement are an ample housekeeping department, hot water heating plant, and a room with a large and complete equipment for taking Roentgen ray photographs of large size. This permits close watching and inspection

of the manner and rate of healing of fractured bones, without disturbing them and inconveniencing the patient by removing bandages or splints.

On the receipt of a patient at the hospital, he is, while on a stretcher, taken by means of an electric elevator to the dispensary for treatment, or, if necessary, to a dressing room and the etherizing room and from there to the operating room. This latter is so arranged as to permit rapid and complete flushing of the floor. Daylight is admitted from two sides and the ceiling.

There are four private wards and two larger wards of ten beds each. In addition are all the necessary rooms for wound dressing, orderlies, waiting rooms, laboratory and resident physician's apartments. A large solarium is comfortably furnished in which patients can rest in the sunshine. Great care is taken to prevent septic conditions from existing, which would retard recovery of patients.

LOCATION OF RAW MATERIALS.

The situation of the plant gives unexceptional opportunities for receiving and shipping materials, which are unsurpassed by its competitors. The Vermillion ore range is but 690 miles distant by rail, so that if desired, ore may be shipped in the winter, as the practicability of so doing has been demonstrated. The works are 870 miles from the Mesaba mines. Ore is shipped from this region from the port of Two Harbors. Escanaba, the port of the Gogebic region, is 490 miles distant, while by rail, this group of mines is but 400 miles away. The distance from the Marquette mines is no greater. This ore comes by water from Escanaba, as well as do those of the Menominee range, which, by rail, is only 300 miles north of the plant.

Coke, coming all by rail, is had from the Connellsville region of Pennsylvania and Pocahontas region of West Virginia, distant 525 to 625 miles. Limestone of a very fine quality comes from Bloomington and Bedford, Ind.—famous for its excellent stone. These quarries are 175 miles to the south.

In the matter of fuel for steam and gas making, owing to the proximity of the rich Indiana oil fields and the coal mines of Indiana and Illinois, the works are completely independent, for with but a trifling change, either fuel can be used.

The various boiler houses are equipped for burning either oil or coal. The Bessemer converting works, open hearth steel mill, the rail and plate mills each have a gas producer house equipped for gas making for fuel. When these are not in use, oil is used quite as satisfactorily for steel heating, etc.

Thus it is possible at all times to work to the highest advantage, all efforts being made in the direction of large outputs of the best quality of products. This can be done by the use of mechanical processes as much as possible (though there are employed about 3,500 men), coupled with the use of the best raw material, and watched and tested in every step of the manufacture.

DISCUSSION.

Mr. C. E. Stafford: (Manager of the Open Hearth Plate Mill Deptartment.) I wish to say Mr. Windett has given a very full and clear description of these works. You will readily understand that to lead, or at least to keep up with the times and with conditions, a number of improvements are necessary. The most important of these at the present time is the so-called slab mill that has been authorized by the directors, and plans and specifications are being drawn. This slabbing mill possesses some novel features in that it will be used not only as a slabbing mill proper, but also as a blooming mill. The slabbing mill, as most of you may know, consists of two sets of rolls in combination. One set is horizontal, working upon the upper and lower surface of the ingot, and the other set are vertical, working on the side of the ingot. This is necessary with very large ingots, because of the fact that it would be difficult to make tables that would stand turning them over, and moreover the rolls would be very cumbersome. This slabbing mill primarily is to prepare slabs for the plate mill. It will increase the production of the mill fully 50 per cent, from the fact that the ingot will be reduced about one-half in size, and in that way of course the production of the two mills, that is the combination of the slabbing mill and the plate mill, will be increased tremendously.

Now, then, the novel feature about this mill is the fact that the vertical rolls can be drawn entirely out of the way of the horizontal, thus leaving those rolls to perform the function of a blooming mill. The central portion of this roll is what we ordinarily call a little bull-head, that is, it has a very wide cylindrical surface that will take a slab something like 40 inches wide. Outside of this bull-head are passes which will take an ordinary ingot—and the rolls, I should say, are controlled by screws and hydraulic pressure, so that they can be opened up to any extent within 36 inches. In this wide range we could fill not only all the requirements of the South Works, but also those of other consuming mills.

These rolls are to be driven by two different sets of reversing engines. The rolls, which I should say, are about 32 inches in diameter, are 84 inches long, and driven by a pair of reversing engines 46″ by 60,″ geared 5 to 7. The vertical rolls, about 20 inches in diameter, are to be driven by a pair of 26″ by 30″ engines. This will be done in a building something like 350 feet long by 70 feet wide, and the rolls will be served by what we call the soaking pit furnaces, six in number, and they are served in turn by electric cranes—electric plunger or screw cranes which have automatic tongs. These cranes will elevate the tongs, and the tongs can be revolved and can be opened and shut by power. This, as I have given you, is about the idea that we intend to carry out. The plans and specifications are in the course of preparation at the present time.

In addition to this we are now building a steel foundry. The foundry work at present is carried on in the South Works in the open hearth building. We are just completing a fifty-ton furnace, and this foundry has to be enlarged, and the room is also needed there, so we are putting up a building of some 30x150 feet long to increase the capacity. I should say, in connection with the steel foundry, we have made some very large ingots for shafts, the largest of which weighed about forty tons.

In the Bessemer department the company is about carrying out the ideas contemplated by Mr. Forsyth in his first plans, and that is, removing the vessels weekly if necessary, or whenever desired. These Bessemer converters are arranged with a trunnion-ring, through which the shell of the converter is pushed up and fastened in position. When the lining is thin, or out of shape, this vessel can be withdrawn in the same way and a new one supplied. This, of course, enables the mill to keep up a regular and a large production of Bessemer steel.

It is also in contemplation to establish a central condensing plant at the rolling mills, which will conduce to fuel economy—a very important matter in this region.

It is also proposed to do some compounding of the blast furnace engines. The blast furnaces now are self-contained, as far as the generation of steam from the waste gases is concerned. By compounding and condensing, the steam thereby saved will be available for other purposes.

I believe that these works, as they now are, are small compared to what they will ultimately be. We know that the discovery of the Mesaba ores has put this country on an exporting basis; in fact, it has had this effect on the iron industry throughout the world, as we have already exported our products very largely. Last year we sent pig iron to Germany, rods to England and rails and plate bar; we have also sent rails and bridges to Japan and Corea, and so on. Therefore, I say, on this account these works are, I think, small compared to what they will be ultimately. We are able to export, although in the center of the continent, because of the very cheap freight we get by the waterways through a large portion of the year.

Mr. Davison (chief chemist): I do not know that I can add anything to what has been said in regard to the plant, except that the chemical part of the establishment is quite complete and extensive, and a large amount of work is done there. I can say that during the year 1897 the number of determinations made was in the neighborhood of 151,000, including analysis of the raw materials going into the furnaces—ore, limestone and coke, the pig iron, spiegeleisen and steel produced, and miscellaneous analysis which are necessary to the proper running of the plant.

The laboratories are three in number, although the main laboratory is the principal one. In addition, there are two mill laboratories one at the Bessemer plant and one at the open-hearth plant made necessary from the fact that certain work

must be done very promptly in order that the metallurgists may get the results and regulate their processes thereby. The number of chemists is about twenty, and the number of determinations monthly will run somewhere in the neighborhood of 13,000. I think that is all I have to say on the chemical side of the work

Albert Reichmann: I would like to ask the chemist if he thinks he will ever be able to tell the physical quality of steel from the chemical standpoint by chemical experiments. I find that in our reports the chemical tests run very uniform, while the physical tests run the other way.

Mr. Davison: Well, that is taking a rather broad view of the matter, it seems to me. I think it will be universally admitted that the physical qualities of steel are determined largely by the chemical composition at present, although it must be admitted that there are a great many things about steel which are not yet understood. The present development of chemical work in steel is largely of an ultimate nature; that is, we simply determine the percentage of the different elements, and we do not determine the exact condition in which they exist in the steel, that is, the different compounds which they represent, and there is yet a good deal of research work to be done, but the ultimate analysis as at present carried out will give a very close approximation of the physical qualities of the steel. And the irregularities of which the gentleman spoke are not due so much, I think, to the chemical analysis being of little value as they are to heterogeneous structure of the steel, improper heat treatment and the mechanical working of the steel. That plays a larger part in some of these cases than the chemical analysis. If the steel is homogeneous and receives proper treatment, I think the ultimate analysis will enable a metallurgist to tell very easily what the steel will do and what its physical properties will be.

Mr. Stafford: It may be of interest to some of the members here to know that we have just completed the making of plates for one of the largest marine boilers—the largest to go on the lakes. This boiler will be some 14 feet 8 inches in diameter, I think, by 12 feet 8 inches long. The plates are about 1½ inch thick, and the steam pressure will be 200 pounds.

We are also making plates for Cramp, of Philadelphia. The boilers will be about the same size, but I should imagine they will carry steam at some lower pressure, as the guages of the plates are somewhat thinner. I speak of their going to Cramp, because it shows the wide field we are able to supply with plates. They come here because we have the largest mill in the country, and they were unable to get those very large plates elsewhere. These boilers, I think some six in number, involved about 200 tons of steel plate.

The Chair: Can you give us any information about armor plates?

Mr. Stafford: I do not know anything about it. This new plant will be able to turn out these plates about 72 inches wide, but

that of course is very small work compared with the armor plate proper. That of course takes a special plant and apparatus, which we may have some day.

Prof. A. M. Feldman: I would like to ask regarding the structure of the solids which are shown in the photographs, whether you can give any information as to what are the spots on the structure, what do they represent in the ingredients in the hollow parts after they are etched out?

Mr. Davison: The specimens are polished and then etched with either nitric acid or iodine, and the different constituents of the steel are differently attacked by this etching; in that way they are made to stand out and when examined through the microscope are revealed clearly. You might compare the different constituents to the different constituents of a rock, say a granite, for example. The carbon exists in different compounds, according to the amount in the steel and according to the heat treatment that the steel has received. For instance, if you take a carbon steel and quench it above a certain elevated temperature the composition will appear uniform, the carbon will be there in the condition of martensite; if a steel is annealed, or allowed to cool slowly from the initial temperature, the constituents will vary according to the percentage of carbon present in the steel. With a very low carbon the principal constituent will be ferrite, or carbonless iron, and, as the carbon increases, increasing amounts of pearlyte will appear; when the point of saturation is reached, about 80 per cent, varying a little in accordance with the conditions, we find cementite, which is a very hard constituent, that, under the microscope, has a peculiar metallic appearance, being less acted upon by the acid or iodine than the other constituents. In this way we differentiate by the etching these different constituents, and the amount of carbon in any given steel can be approximately told. Not only that, but by the size of the grain and its appearance we can tell what the treatment of the steel has been, whether it has been treated at too high a temperature, whether it has received much working, or whether it is the original ingot metal which has received no working at all.

Prof. Feldman: I would like to ask Mr. Windett whether the gas they produce is cheaper than the naphtha oil, or whatever oil it is, to use in the open hearth furnaces.

Mr. Windett: We made some investigations of that matter at the time we made the change, and we found that the method of treatment, in view of all the conditions, was satisfactory, so that the practice has been kept up, although should commercial requirements necessitate it, a change from oil gas to producer gas could be made with ease and speed. Metallurgical operations would not suffer by a change of fuel.

Mr. Feldman: Is it cheaper? I know it is more convenient.

Mr. Windett: If all the conditions are favorable.

Mr. T. L. Condron: Regarding the slabbing mill, what will be its probable effect upon the physical quality of plates? That is,

what relation will probably exist between the present differences between "front tests" and "back tests" of the same plate as now made, and the differences which may be looked for between tests of top and bottom slabs made from the same ingot after slabbing mill is in operation?

Mr. Stafford: There would probably be more segregation in the larger ingot. By very careful experiments on the small mass of steel I understand that they are able to detect that there is some segregation in all cases. Now with the larger ingot that we produce, there probably would be more segregation, but you have in this large ingot many slabs, that is, you produce many plates, and you would put the upper part in which the segregation would be greatest into a secondary product. The lower part would probably go into the better quality. There is no difference I take it in the amount of segregation—there may be a difference in the amount but it exists in the present form, and will exist when we cast in large ingots. There may not be quite so much variation in a good, small plate as now where it is cast from a small ingot.

Mr. Condron: As I understand, Mr. Stafford, the slabbing will result in a more uniform product of steel in a given area. That is, you can differentiate your steel into different grades better from the large ingots than where smaller ingots are rolled directly into plates? The upper part of the ingot may then be reserved for a different grade of plate, giving you more uniform products. If I understand rightly, by slabbing and separating into first and second-class plate, you will be able to eliminate the segregated part of the ingot from your selected stock.

Mr. Stafford: Yes, I am glad you brought that out. At present, in rolling plates directly from the ingot, we are obliged to throw away the larger portion of that scrap of the plate just on that account, and the larger the ingot the more we are obliged to throw away. Many of you will remember in the Congressional investigation of the navy plates, that Mr. Schwab stated that they were obliged to cut away in that case from 1/3 to 1/2 of the ingot in order to produce slabs, or an armor plate that was free from this segregation. In the same way with rolling smaller ingots, we are obliged to cut off more or less of one in the same degree as is necessary in a large ingot.

Mr. J. C. Bley: I would like to inquire about the number and types of engines that you use.

Mr. Windett: You mean the stationary engines?

Mr. Bley: Yes, the stationary engines, what is the prevailing type?

Mr. Windett: At the blast furnaces, for instance, the blowing engines in use now are simple engines, and condensing; the blowing engines are all vertical, the air cylinder being on the top. That is partly to save floor space. Most of the pumps in the blast furnaces are compound condensing duplex of the Worthington type. In the Bessemer mill, of the blowing engines, two are

of the vertical kind as at the blast furnaces, only they deliver air at 20 to 23 pounds pressure, and two others are horizontal. These are rather old in type and make. It is expected to compound the vertical engines and put on probably some type of condenser.

In the rail mill the three principal engines are the engines driving the three rolls. They are all the simple expansion horizontal Porter Allen type. Those are going to be compounded and condensed also.

In addition to that, there are a large number of small engines driving the tables, those are reversing engines; they are either the small Crane type, that is the Crane Manufacturing Co.'s type, or an engine we make ourselves, about 9x16 cylinders, or 8x12.

The engine that runs the hot saws is a Westinghouse simple expansion engine that runs at high speed and drives the saws by belt connection.

The machine shop engine is a compound condensing engine manufactured at the works. In the plate mill the rail train engine is the Porter Allen. In the electric power station plate mill we have one 500 horse-power McIntosh and Seymour engine, and two 250 horse-power compound condensing engines of the Lake Erie Works.

Mr. Bley: In the compounds, are they mostly tandem or cross?

Mr. Windett: All the pumps that are compound are tandems, and the other compound engines are cross-compounds.

Mr. Bley: Do you have many of the Corliss valve gears?

Mr. Windett: We have some Corliss valve gears in the engines for blast furnaces 1-4. In compounding the blast furnace engines we expect to displace the present valve gear and may introduce the Corliss. The compounding will require the displacement of the present cylinder, the adopting of a new high pressure and a new low pressure cylinder. The plans for this have been drawn up and specifications sent out asking for bids. That is about as far as we have got on that, but the work is going ahead very quickly.

Mr. Bley: I would like to ask if the X-ray has been used for determining the internal structure of large masses of steel?

Mr. Windett: Nothing has been done with the X-ray outside of the hospital work, but we have done more or less work in photographing steel under the microscope. Of course, that simply shows the surface condition.

XXVII.

A VIEW AND DESCRIPTION OF THE BED OF A PREHISTORIC OR GLACIAL LAKE, BETWEEN SUMMIT AND LAMONT, ILL.

By OSSIAN GUTHRIE—Mem. W. S. E.

Figure 283, on page 681, Volume II, Journal (W.S. E.), shows a section of a bed of a prehistoric or glacial lake, which is fully described in my article on "Relics Turned up in the Drainage Canal," page 472, Volume I, Journal (W. S. E.). On account of this lake occupying the summit of the divide between Lake Michigan and the Mississippi valley, the late Mr. Chas. H. Ford and myself gave it the name of "Summit Lake." The group of boulders in this view (Fig. 283) are some of the glacial implements that carved out this prehistoric or glacial lake, and are here shown just as the glacier left them, approximately, 8,000 years ago. The oval-shaped boulder at the right, in Fig. 283, is the gray granite boulder which now forms the cap-stone of the Marquette Monument at Summit, Illinois, shown in Fig. 277, page 677, Volume II, Journal (W. S. E.). This boulder, which is glacial marked on all sides, may possibly be a native of Hudson's Bay. The bed-rock beneath the mass of drift here as elsewhere throughout the length of the lake is glacial planed, as shown in Fig. 350, herewith.

FIG. 350. Glacial Planed Surface of the Bed Rock underlying the Glacial or Prehistoric Lake.

XXVIII.

AN ENGINEERING EDUCATION.

"WHAT LINES SHOULD BE LAID DOWN AS A GUIDE FOR TRAINING AN ENGINEER?"

A Discussion, November 3, 1897.

Mr. J. C. Bley: Mr. Chairman, on the spur of the moment, I suggest as a topic for discussion the consideration of an engineering education, what lines should be laid down as a guide for training an engineer? Suppose, for example, one of you desired to train a boy in civil engineerning, what lines of work would you want him to pursue, how much pure mathematics, how much physics, and how much actual construction work, as far as that work is possible in college, and so on in other lines? I believe that we ought to do in education as we are doing in other work, we ought to go to the workman and ascertain what things he has found useful and the things that he has found of little use; the things that are useful as training, the things that are useful as tools, and various matters of that kind; and the practicing engineer is the workman to whom we would have to appeal in that case.

Mr. O. Chanute: Mr. Chairman, I believe this is the subject that led to the formation of the Society consisting of a number of teachers and professors in civil engineering schools of the country. This association was called in 1893, and was one of the divisions into which the engineering Congress which was held in this city was divided. I met one of the professors who was in that society last summer, and he told me that they had been debating over that question ever since, and that they had not made much progress; they have held one or two annual sessions, they have published several volumes of transactions, and they are no nearer to an agreement upon what is the best possible course of training for an engineer than they were at the beginning. It is possible that some engineers might throw some additional light on the subject through their own practical work, but so far as I am aware, the question is yet an open one.

Mr. G. A. M. Liljencrantz: Concerning this question, there is one thing that I consider of great value, and that is: When a young man starts in to study a certain branch, whether it be civil or mechanical engineering, it will be to his advantage to spend his vacations somewhere in actual work; for instance, for a mechanical engineer, if he can get a position in a workshop then study afterwards, the theoretical part will be much easier acquired, and the same with any other branch. Take, for example, the branch of surveying If the student has been out in the field,

as rod-man or running the level, he will find it much easier afterwards to understand and remember what he studies in that line. If a certain line has been decided upon more time and more study should be devoted to that particular line, but in most colleges, I presume, each student must go through a fixed course in each branch, as was the case where I studied, though that is thirty-one years ago, and methods may be different now. We had to study all the different branches according to the established curriculum, and therefore could not study more thoroughly any particular one, as should be done if a person is going to devote himself more exclusively to a particular branch.

Mr. Isham Randolph: I remember last winter we had a meeting at the Technical Club of the faculty and alumni of the Troy School, and several of the faculty of the Chicago University, of the Northwestern University and several of the schools in and near Chicago, and this same subject was up for discussion then. At that meeting I repeated a conversation which I had had with Professor Fuertes, of Cornell University. When there, three years ago, in conversing with him, I said that if I trained up either of my boys to follow my profession, I wanted to give him a good, common-school education, ground him as well as I could in mathematics, then put him in the field and on construction for about two years before sending him to college, that I thought then he would know the value of the things he was going to study and would be able to apply himself to it. Professor Fuertes said, "You would be making one of the greatest mistakes of your life, if that is the way you are going to treat your boy. You ought to give him his scientific education first, and then let him work all he wants to after that."

I repeated this conversation at this meeting, and it was discussed quite fully there. Professor Palmer C. Ricketts, Director of the Renssalaer Polytechnic, sided with me in that discussion, others took the ground of Professor Fuertes. It was discussed at considerable length and left right there.

Mr. F. G. Gasche: Mr. Chairman, if suggestions concerning the proper training of a youth to become an engineer are in order, it is well to prepare the way for such discussion as may follow by a certain observation, viz.: The problem will be indeterminate so long as the education of a young man continues to involve so many intricacies.

One of the requirements, I think, previous to the analysis of the controlling factors of the case, would be the definition of the qualifications of an engineer; what kind of an individual you would propose to make of the candidate for instruction. Other complications would arise in the difference of physical constitution and temperament of the students. All these things will determine the receptive capacity of the embryo engineer such that the proper educational training of the youth will begin and end as a special problem for the individual.

J. W. Beardsley: Mr. Chairman, the old darkey evidently re-

ferred to one of the essentials of the engineer when he analyzed senses. He said that everybody had five senses, but that there were seven senses in all. A good many men had common sense, but only the very best people had good "hoss" sense, which was the seventh and most rare of all the senses. Engineering has been defined as scientific guess-work combined with good common sense.

It seems to me that this Society is discussing this question from two standpoints—as a trade and as a profession. Past conditions have existed in the country which have made engineering a trade, but present conditions are radically tending towards making it a profession. I would prefer to consider the question from the latter standpoint.

It is a law of psychology that the power of the average youth to acquire facts and store them up for future use is greater than that of the average adult. Memory is the more readily impressed and the more retentive. The demand of engineering questions upon science, mathematics and natural laws is almost limitless. Specialization should rest upon the strongest foundation attainable, and the young engineer should not be deprived of the peculiar value of certain years in acquiring such foundations. Nearly all of our technical schools require sufficient laboratory and field practice to meet the demands of the practical man. They are increasing both the number and range of theoretical subjects, and they are discriminating more closely in granting a degree.

I believe that the scientifically trained man will receive far more actual experience from the same work and in the same time than the practical man, and that in the end the quantity and quality of his work will be far superior. However, no school can complete the studies required in actual work. No technical training can offset lack of ability to work, and the graduate who fails to continue his studies must fall far behind the practical man who possesses the power and determination to solve each problem encountered.

Mr. Bley: Mr. Chairman, the question as I have looked at it, has called out several other questions; for instance, I had an engineer tell me one time, that he regarded the time he spent on calculus as entirely wasted. I had another engineer, a member of this Society, whom I understood to be a very thorough mathematician when at school, say that he wished he had enough calculus so that he could use it, it was of no practical use to him in the limited understanding he now has of calculus. Now then, if that is the case, the question comes up, how much shall we study calculus? Should we study allied subjects as quaternions, and space, analysis and things of that sort? They used to consider that one of the foundation stones of engineering was mathematics, but in the last two or three years, in current periodicals, there have been expressions given to the idea that you could have good, constructive engineers who were poor mathematicians, and I con-

fess that in my observation I have found one or two men who answer that statement, men who are not good mathematicians but are good constructive engineers. They will get out a machine on time, their work will be neatly done, and the machine will fulfill the office for which it was designed.

Then another question comes up; shall we make a physicist of the man, an experimentalist, or shall we make him like people who have no theoretical knowledge, but from natural insight and from time devoted to a branch of work becomes proficient in it. That adds a little to the complication of the subject. For example, shall we train a man who can go through a series of extensive experiments and work out the result, or shall we train men rather to be able to use material that has been accumulated by others and is accepted by everyone as fairly reliable? I understand we train an engineer for active work. Now which will equip him the best for that work? Those are some of the ideas I had in raising the question.

Mr. Victor Windett: Mr. Chairman, an engineer ought to be thoroughly grounded in mathematics, and by all means give him enough calculus to be able to apply it when necessary, and there are times when it is necessary. That is, there are times when the use of calculus will save much crude approximation or labor in reaching desired results. The college student does not graduate with a storehouse of knowledge, either of facts or theory. He has learned to think and how to use the knowledge of which he has learned the location.

A few months ago there appeared in the "Engineering News" a letter written by the chief engineer of one of the western roads to the father of a young graduate. The point was that this country had now reached a point where railroad expansion will be in comparatively small steps. Consequently the number of civil engineers required for railroad building is small. He mentioned the lack of engineering trained men in the operative department and recommended a graduate of college taking a position as section hand for some months, nearly a year, then if he showed ability he might be made a section foreman, and after several years he might reach the position of a division superintendent. This is a rigorous training. If a man has the physique needed he can stand this. I know a young man who tried this. He entered a section gang. The first day he unloaded rails from flat cars, and went home fatigued, the next day he continued on this work, the third day unloaded and spaced ties. The following morning he did not appear at work. His mates went to his lodgings and found him exhausted: On being brought to Chicago he was found to have sustained a lesion of a valve of the heart and now is forbidden work for a year. The fellow had grit and worked beyond his powers, being not very strong at the best.

Another college graduate, of a robust constitution, went into the shops, starting in the casting yard, then working at the bench and machine work. Now he is a prosperous master mechanic in a

large plant. Thus it seems that this question of education, when carried beyond the teaching how to think and work, is a problem for the individual and not for generalization.

Mr. Randolph: One of my good friends in this city is a gentleman, a Scotchman by birth, who gave me this page from his life's history. He said that he landed in New York—it must have been, I should say, about thirty-five years ago—after having been shipwrecked. He said he had the clothes on his back, and a plug hat, and a dollar or two in his pocket. He had been well educated in Scotland, and had served his apprenticeship in a surveyor's office. He struck over into New Jersey, looking for work, and found a railroad in process of construction. He asked for work and was given a wheelbarrow. He said that he started in at noon; by night he wondered whether he did have manhood enough to tackle that wheelbarrow the next day. He went to bed feeling as if he never would be able to do anything again. But with the night's rest his courage rallied, and he went back to that wheelbarrow and wheeled it all the next day. By this time the foreman had begun to take some little interest in him and told him he would give him something easier the next day. The next day he gave him a shovel to load the wheelbarrow with, and his back ached as badly that night as it did the night before from the wheelbarrow. But the foreman was in some trouble with his time-book. My friend saw this, and he told him that he knew something about accounts, and helped him out, fixing up his time-book for him. That led in a day or two to his being given a gang of three or four men to do some digging, digging out the foundation of a culvert, I think, and from that he was made foreman of a small gang on that work. When he finished that he drifted out West and got a position as section hand on the Rock Island road. He worked at that for a short time and was finally made foreman of the gang. His time-books and accounts were so nicely kept that he was sent for to come into the Chicago office as clerk, but he said he had no idea of doing that. He did not propose to stick at a clerkship. He stuck to his foremanship and studied law at night, and finally he got a clerkship in a store, and his friends found out that he knew something about law and they used to sponge law off of him until he got tired of that. Finally he got a clerkship in a bank. You will think it hard to go through such vicissitudes as his were, but at the present time he is one of the wealthy men of Chicago, and he has made that wealth by hard work and good, sound Scotch judgment. But if he had not had the gr t he showed in the beginning, I doubt whether he would have landed where he is now.

Mr. J. B. Rohrer: A suggestion was made by one of the speakers that it was better for the student to attend college when he was young than when he had attained more mature years, because the youth would more readily imbibe the proper data and information and would place it in his storehouse to be be used in future operations. I think that suggestion is one that ought to

be taken into consideration, because, if the student who starts to study civil engineering or any other profession, starts in too young, he may be too young to take in the data and properly arrange it in his storehouse, which would be as unsatisfactory as if he was too old to start in to take it. I think that that is as much a matter to be considered as what form, whether it shall be practical or theoretical. My idea is that a young man should be about twenty possibly to start in to study one of these professions, and between the time he leaves his common school education until the time to go to college I think it is a good thing to take practical lessons as Mr. Randolph suggests, get a few years' practice in the field. I think then he would be of such an age that he would appreciate what he had to study, as well as young enough to thoroughly absorb it and absorb it easily, and at the same time have the advantage of his practical experience. Of course, some of this I appreciate just from my own standpoint. If I had known more about certain practical things whilst at college, I could have paid more attention and would more thoroughly have appreciated them. On the other hand, I think possibly, if I had been a shade older when I went to college, I might have absorbed the data just as easily as if I had the practical experience, but possibly, taking practical experience and a little more age, both of them together might have made me more able to thoroughly appreciate what I studied, not that I did not take some with me, I hope, but not as much as I might have done.

Mr. Liljencrantz: It is the rule in Sweden that when a mechanical engineer has graduated, passed his examination from the institution, that he shall practice in a machine shop for three years before he can be received anywhere in a responsible position in such a shop. One of my friends, who had passed his examination, went to the Motala machine shop, where Captain Carlsund was the general manager or superintendent, and he was very cross or disagreeable to deal with. This friend of mine was very short, quite stout, and had a very jolly face. He came in to Captain Carlsund, who asked what he wanted. He said he wanted to get a position.' The Captain said: "There isn't any place for you." He left and came back about three or four days later. "What are you here for again?" "I came to see if there hadn't been a vacancy." "There isn't any, and there won't be any." So he went off and waited a week. He came back the third time, and Captain Carlsund was pretty severe and told him "I don't know what you are running here for; I have told you there isn't any place, and won't be any for you; there is no use of you running back here any more." "Well," said he, "I suppose that must be so; it seems strange to me though, that in such a large shop as this there shouldn't be a place for such a little fellow as I am." He was invited into the office and got the position.

Mr. Randolph: Professor Ricketts, in the discussion I spoke of,

seemed rather against manual training schools. He said he thought they ought to be used with a great deal of care. That his experience was that there were a great many boys who, while they had bright but lazy minds, much preferred to de-develop their fingers to their minds, and if they were permitted to go into the manual training schools that they applied themselves very diligenty to making a little engine or something of that sort to the detriment of their mental training, and for that reason he thought that parents and guardians should exercise very great care in sending their children to manual training school. It was an idea which I never heard suggested before, and I think there is a good deal in it.

CLOSURE.

By J. C. Bley, Mem. W. S. E.

Few subjects can be very fully and systematically considered in an impromptu discussion, but such discussions may lead to more systematic work later on. The main points brought out in the talk are briefly as follows:

Mr. Chanute stated that civil engineering teachers formed a society for the solution of this problem in 1893, and that they are still solving it. He thinks some engineers might furnish additional light but that the question is still open. Mr. Gasche believes the problem indeterminate in general, and he and Mr. Windett believe each individual case must be solved independently, Mr. Liljencrantz, Mr. Randolph and Mr. Rohrer agree in wanting practical work before or during the intervals of college or theoretical training. The two former have great faith in grit, but who has not? Mr. Randolph is inclined to follow Prof. Ricketts, in shying at manual training when he is leading "bright but lazy minds." Mr. Beardsley wants the young engineer to be fed upon "hoss" sense and lots of other things while he is young because he is then a better feeder than he is later. But Mr. Rohrer wants him to go a little slow until he can see that all he gets may be good for him. Mr. Beardsley believes also that a scientific man gets more out of an experience than a practical man and will beat him in the long run. Mr. Windett thinks an engineer should be a good mathematician and be able to use calculus, and that a college student does not graduate the owner of a store house of facts or theories, but that he knows where the store is and knows how to run it.

It seems to me, in conclusion, that the question must remain open as long as the conditions upon which it is based are subject to change, but that is not saying that we can not get more and more nearly satisfactory answers by continuing the inquiry. We should keep in mind that there are limitations. Students are often restricted in either time or means, and sometimes in both, and colleges in order to be run economically, must limit the elasticity of their courses and students must take the studies of a pre-arranged

course or not at all, in general. This limit of choice of studies is likely to prove troublesome to the mature student who wishes to change his course to suit his judgment and is that far a bar to all vindidual solutions.

When it can be done, it is probably better to let the judgment be matured somewhat by practical experience before going into much theoretical training. For, while it is doubtless true that the boy's mind is more receptive and retentive than a man's mind, it is also true that the mind is hindered by the things it has acquired but makes little use of. So we get around to apply Herbert Spencer's question, "What knowledge is of most worth" to engineering, and in the answer we are inclined to compromise in some way on the scientific and the practical. For, if Mr. Beardsley's scientific man gets more out of an experience than the practical man, the latter will even up matters by getting out of an ordinary hole the quicker, and if the scientist wins in the long run he is likely to lose in many short runs meantime. Each could make use of the others experience to advantage, and the object of the schools should be to give their students the benefit of both experiences as far as possible.

While the student is required to take studies as laid down in a pre-arranged course it will be important to have those studies well chosen. As to the suitableness of studies for a given trade or profession, the majority of intelligent men in that field of practical work ought to be able to give the most satisfactory answer by stating what they have found to be useful and what of little use. A compilation of such information should indicate what is practically essential and non-essential, and courses could be arranged in the light of that experience.

The studies being chosen, they should be pursued within the range of their application to the general subject as thoroughly as time and means will permit, since the usefulness of many branches of study, like calculus for example, depends upon the thoroughness of their mastery by the student.

ABSTRACTS OF PAPERS IN FOREIGN AND AMERICAN TRANSLATIONS AND PERIODICALS.

THE DREAM OF NAVIGATORS.

By Capt. A. S. Crowninshield, U. S. N.

(From the North American Review, December, 1897.)

To those who have been waiting for the arousing of public interest in this great project, it seems as if the time had at last arrived when thinking men, as well as many who are not of a serious turn of mind, admit the imperative necessity of a highway of rapid transit between the two great oceans which all but encircle our continent.

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Japan was formerly looked upon as a far-distant country, composed of a group of islands inhabited by an interesting people, having no political relations with the western world. Presto! and all is changed. With new rulers, a new and liberal government, a desire to expand, followed by the adoption of western methods, railroads, steamships, with a foreign commerce, an army, and, what particularly concerns us, a modern navy, she appears at our doors as a power demanding recognition.

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Beyond Japan, a few hundred miles to the west, lies the Chinese Empire, with its *four hundred millions* of people! While Japan has advanced China has remained dormant. But will this continue? Given new rulers, a new form of government, and the adoption of western ideas, and China will throw off its yoke of conservatism, and then our Pacific States will be confronted with a second Asiatic power many times greater than Japan.

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The moment that a waterway is opened across Central America, the producers of our Pacific states will be brought eight thousand miles nearer to a market.

For years past there have been exported annually from California and Oregon nearly a million tons of wheat, every bushel of which has gone around Cape Horn! All grain exported from California is at present taken to the Pacific port of shipment by the railroads.

This projected waterway will also induce immigration, and thus develop that section of our country far more than it has ever been developed by the transcontinental railways.

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As a political factor in increasing the influence and power of this country in the Pacific, the canal will be far-reaching. To-day, if the United States were forced into a war with Japan over possession of the Hawaiian Islands, which to her are stepping stones

to our continent, we should be placed at a great disadvantage; for it is a fact that at this moment Japan's naval force is greater than our own Pacific and Asiatic squadrons combined. To reinforce our Pacific fleet we should be obliged to send ships from our Atlantic squadron, forcing them to make a voyage of twelve thousand miles, thus consuming many weeks, whereas, with the canal in existence, our powerful North Atlantic squadron could be *put into the Pacific within a week!* Thus would the canal enable us to more than double our naval strength in the Pacific.

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Commission after commission has reported favorably as to the feasibility of the Nicaragua Canal. Exhaustive surveys by our government, as well as by private companies have been made, all showing that this route is not only practicable, but that it possesses natural advantages far above all others.

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We should be wise in our generation, and by legislation and such other steps as may be necessary, inaugurate without further delay the work of completing the Nicaragua Canal. Let us pierce the isthmus at the one spot which nature has already pointed out, and thus fulfill what has been for centuries the hope of commerce and the dream of navigators.

THE NICARAGUA CANAL.

By HERNANDO DE SOTO MONEY, United States Senator from Mississippi.

(From Munsey's Magazine, February, 1898.)

From the time of the earliest Spanish discoverers to the Scotchman Paterson, half-way between Columbus and our own day, English, French, Spanish and American adventurers and schemers have dreamed of piercing the American isthmus.

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Presidents, secretaries and senators, supported by the press, have declared the canal an American question, to be controlled by America; and when the French began work at Panama, there were frequent official assertions that, by whomsoever made, an interoceanic canal would be considered a part of the coast line of the United States.

Negotiations should at once be commenced with Great Britain to abrogate the Clayton-Bulwer treaty, in express terms. England should be allowed no excuse for any interference or partnership in control or protectorate of the canal or adjacent territory.

The next step would be to negotiate treaties with Nicaragua and Costa Rica, by which, under suitable concessions from those states, the United States, as a government, would undertake to complete, maintain and control the canal.

While the diplomat is pursuing his labors, the engineer should be at work. A board of competent engineers, drawn from the army, navy and civil life, with ample funds and unlimited as to

time, should thoroughly survey all the proposed routes in Nicaragua, and on its report it could be determined whether the canal would justify the cost.

It is confidently believed, in advance of such an exhaustive survey, that private capital cannot be induced to invest in the enterprise. The United States must decide whether, if there were no dividends, or even a pecuniary loss, our political and commercial interests would warrant us in assuming the burden. The commission of 1895, which was ordered to report on the "feasibility, permanence and cost of the construction and completion of the canal," was unable, because of inadequate data, to draw definite conclusions, and recommended a more complete survey. The facts given by the Maritime Company's engineers were found insufficient to settle any one of the points under examination. In truth, that commission left the disagreeable impression that unless a future survey should develop conditions more favorable than those disclosed up to that time, the decision as to the whole project must be adverse.

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While not undertaking to go minutely into the estimate of the amount of tonnage from different sources which has been represented as tributary to the canal, it is safe to say that the account has been too rose-colored. This is a day of larger accumulations of capital and of lower interest than ever before. Yet the Nicaragua Canal remains without subscribers.

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While the operation of the Nicaragua Canal may be at a constant loss, nevertheless the advantage to American commerce may be so great, and our wealth be so increased, that the expense may be amply compensated.

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It has been claimed that our west coast would be more easily defended by the ready transfer of our warships from the Atlantic to the Pacific; but it should be remembered that the fleets of Great Britain, Germany and France could be as readily transferred by the same means, so that the attack would be as much facilitated as the defense. It is disputable, therefore, whether our security would be more assured without a considerable increase of our navy. But whatever the cost of such an increase might be to the United States, it would be preferable to the control of the canal by any foreign nation, or even a partnership with us in the control. The first would minimize American prestige in the Central and South American states, and the second would be a virtual surrender of the Monroe doctrine, which this government cannot afford, and would not make.

PROJECTS FOR AN ISTHMIAN CANAL.

By the Hon. David Turpie.

(From Harper's New Monthly Magazine, February, 1898.)

All the commercial countries of the civilized world have to-

more than a century heartily favored the construction of a navigable waterway across the Central American isthmus. There is not a member or any government or legislative assembly in Christendom who has ever entertained or declared any sort of opposition or hostility to that enterprise. The execution of such a design has been the desire of all nations, often attempted, anxiously waited for, baffled only by the extreme difficulty of its accomplishment.

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Gen. Grant, when president of the United States, gravely impressed with the importance of this proposed work, and always very favorable to the Nicaragua route, recommended to Congress the appointment of a commission to make an inspection and examination of the same. This commission was duly selected, performed the duty assigned to it, and made its report, together with an estimate of the cost of the construction. This estimate, provisional in its character, placed the necessary expenditure for the building and completion of such canal by the Nicaragua route at $140,000,000. After this report, which was made November 18, 1874, nothing further was done by President Grant or by Congress in the premises.

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It is proper to say that the Panama Canal Company has always been, and yet is, a private corporation. It is not a government work, and no congress or parliament has ever appropriated a dollar or pledged the public credit in any way in aid of the enterprise.

The most recent attempt to exploit the project of a canal by the Nicaragua route has been made by a corporation styled the Maritime Canal Company of Nicaragua. It began, as others before it had begun, by obtaining concessions from the two Central American republics which own the territory passed through by the line of the projected canal, Costa Rica and Nicaragua. These concessions bear date April 12, 1887. They allowed ten years for the building of the canal, and the Nicaragua concessions expired, by their own terms, on the 12th day of April, 1897.

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The project, as a financial investment, had been blacklisted upon every exchange and market of both Europe and America for fifty years before. Capitalists had no confidence in the company, or in its plan of execution. The movement for stock subscriptions was a total failure. The company was left without money or credit, just as it had been in the beginning.

The Maritime Canal Company of Nicaragua had been incorporated by an act of Congress on the 28th day of February, 1889. One of the provisions of its charter is as follows:

"*Provided, however,* That nothing in this act contained shall be so construed as to commit the United States to any pecuniary liability whatever for or on account of said company; nor shall the United States be held in any wise liable or responsible in any form

or by any implication for any debt, or liability in any form, which said company may incur, nor be held as guaranteeing any engagement or contract of said company, or as having assumed, by virtue of this act, any responsibility for the acts or proceedings of said company in any foreign country, or contracts or engagements entered into in the United States."

* * *

Congress adhered to its former action, and did not grant any subsidy to the company. In deference, however, to the character of the enterprise, and to the interests of our sister Central American republics, a law was passed appropriating a sum of money and authorizing the appointment of a commission of three engineers, one from the army, one from the navy, and one from civil life, to make an inspection of the line and route of the proposed Nicaragua Canal as laid out by the company, and especially to make a detailed estimate of the cost of execution. This commission went personally to the site and line of the canal route. They made a skilful and careful examination of the line, a particular calculation by itemized sections of the cost of completion, returned home, finished their report, and filed it on the 7th day of February, 1896.

This report by the government board of engineers, compared with the report of the engineers of the company, became the subject of quite animated discussion and of special notice in the Senate in the winter of 1897.

* * *

To summarize this state of affairs, the total estimate of the Canal company for the construction and completion of the canal is $66,466,880. The estimate of the government board of engineers is $133,472,893, twice that of the company, and within $7,000,000 of the former estimate made by the commission appointed by Pres. Grant in 1874.

* * *

There is surely no valid reason why, if our government is to furnish the funds for the construction of the canal, it should not also directly control and administer the same, in conjunction with the Central American governments interested, under a treaty with them concluded for that purpose.

There is certainly no reason why the government of the United States, in relation to the building, completion, and future operation of this great canal, should treat with a private corporation whose only claim to consideration rests in the total discredit and disaster which have accompanied its attempt in the execution of the work.

And it is to be especially noted that although the government of Nicaragua publicly charges the Maritime Canal Company with violations of the concession, and with inexcusable breaches of contract, yet neither of the Central American republics has made any opposition to the enterprise itself, or to the construction of the canal by our government.

A condition quite fortunate is thus shown, because it is not possible that any power could build or operate this ship canal in the country of an unfriendly population. This work is not like that of Suez or Corinth. Those are canals built by excavation on the sea level, as before stated. To destroy them would require the slow process of the excavation of another channel to drain away their waters, or the filling up of the present one in use; but the Nicaragua canal, with its double system of dams and locks, would be peculiarly sensitive and liable to injury, by either public or private enemies, as there are many places along the line at which an hour's work with the pick and shovel, to say nothing of the use of explosives, would let the water rapidly escape, and so wreck the whole system.

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Congress, in accordance with this recommendation, on the 4th day of June, 1897, authorized the appointment of a commission of engineers to make another survey and estimate of the cost of construction, and to further examine as to the proper route, and as to the feasibility of the Nicaragua canal.

This commission has since been appointed by Pres. McKinley, and is now engaged in the performance of its duty. Our government is awaiting its report.

Three things are necessary to the consummation of this enterprise: First, funds to be furnished by the government of the United States. Second, the perfect amity and friendly co-operation of Nicaragua and Costa Rica in the work. Third, a reasonable assurance of its feasibility, and of the amount of money needed to construct and complete it.

The three republics could under such auspices thus give to the world an American canal under American control.

"BACTERIOLOGY."

By GERMAN SIMS WOODHEAD, M. D.

(*Abstract from Proceedings Institution of Civil Engineers [England]. Vol. CXXX. 1897.*)

We have already mentioned that bacteria may be roughly divided into two classes—those which have the power of taking up oxygen from the air and those which, although they require oxygen, as a rule obtain it from carbo-hydrates or from substances that contain a considerable quantity of oxygen in their composition, but which, deprived of their oxygen, rapidly break down to form substances of a less complex nature. It must be remembered, however, in this connection that no hard and fast line can be drawn between aerobes and anaerobes, as they are called that is, between those organisms that require air and those organisms that can do without it, as under certain conditions an aerobic organism can lead an anaerobic existence, that is, can so far adapt itself to circumstances that when it is removed from air it makes violent efforts to obtain its oxygen from substances that contain

oxygen in considerable quantities, taking them up best, of course, from those substances in which the oxygen is in a condition of loose combination; whilst, on the other hand, an anaerobic organism may grow fairly luxuriantly in the presence of air, although it is found that, under certain circumstances, it does not give rise to its characteristic products. Those organisms, which have the power of adapting themselves to their surroundings, are usually described as facultative aerobes and anaerobes, but although they can so far adapt themselves to the altered conditions, their life history and the results of their vital activity are considerably modified. Let us take as an example one that actually occurs in nature. If instead of water, as above, some surface soil is taken for the seed material for gelatine plates, the individual organisms contained in the soil are isolated; if, at the same time, a very minute fragment of this soil be put into gelatine containing a small quantity (2 per cent) of grape sugar, or a still smaller quantity (½ per cent) of formate of soda, two things will soon be noticeable. In the gelatine plate culture, especially if the layer of gelatine be of some little thickness, it will be observed that on the surface numerous colonies grow with very great rapidity, some of them producing color, others of them liquefying the gelatine, the whole of the organisms on the surface showing luxuriant growth. Just beneath the surface of the gelatine, and down in the substance, will be seen a number of small brown points, which are certainly colonies of organisms, but they progress so slowly and to such small size that it is evident that the conditions for their growth are not so favorable as are those on the surface, the only difference in this case being, apparently, that those on the surface have a plentiful supply of oxygen, whilst those in the depth do not receive this supply, although there is a small quantity, or they could not grow at all. Now, examining the formate of soda gelatine in the test tube, the organisms on the surface will still be seen to be growing, though not so luxuriantly, as a rule, as on the plate. Near the surface round colonies may also be seen, but down in the substance of the gelatine large colonies, sometimes liquefying the gelatine, sometimes producing gas in considerable quantity, are found. These are the anaerobic organisms which are breaking down the gelatine in the absence of air, just as those on the surface break down the gelatine in its presence. It will be found that in soil taken from very near the surface the number of anaerobic organisms, as compared with the aerobic organisms, is comparatively small. If, however, we take soil from a greater depth and treat it in the same way, the proportion of anaerobic to aerobic organisms is much larger, and going still deeper we come to a layer in which practically only anaerobic bacteria are found, whilst in deeper layers still there are no organisms of any kind.

In nature the process of decomposition of organic matter goes on most readily in these superficial layers of earth, and in the presence of the atmosphere, and the porous soil may be said to

take the place of spongy platinum, in which, as we know, oxidation takes place very readily. The upper surface of this porous soil, usually well supplied with air and moisture and organic matter, is a capital feeding-ground for micro-organisms, which, breaking up its materials, oxidize them into substances which are capable of being utilized by plants. Most of the organic matter brought to the surface of the soil is broken down by these aerobic organisms, air being carried down along with the rain or sewage, and then, as this organic matter is broken up, some of its constituents are used by the bacteria, and others are, during the breaking down of the molecule, left in a nascent condition ready for oxidation by the air that has been left by the organisms. The anaerobic organisms found in the deeper layers of the soil, as we have indicated, give rise to a second kind of decomposition. A certain proportion of the organic matter escapes the action of the aerobic organisms, but it has still to run the gauntlet of the anaerobes. It is assumed that, having been washed deeper into the soil and living, as it were, at some distance from the atmosphere, these anaerobic organisms (originally aerobic) have been unable to obtain free oxygen, and have thus been compelled to develop the power of wresting oxygen by force, as it were, from the oxygen-containing bodies that come down to them from the surface, usually using part only of the combined oxygen, and setting free another part to be used up in the oxidation of portions of the organic matter that still remains. So completely do these organisms use up the food that has come from the surface that at a depth of about 12 feet no micro-organisms at all can, as a rule, be found. The relation of this to our water supply and to the treatment of sewage is obviously one of extreme importance. As I have stated elsewhere, if water can be taken from near the surface of the soil in which there is a large quantity of organic matter present, there must necessarily be numerous aerobic putrefactive organisms in it, whilst surface drainage-water will invariably contain those organisms usually found in sewage and in excrement. If, however, water be taken directly from the deeper layers of soil, putrefactive organisms are usually absent, but a number of what are called water-organisms, non-spore-bearing harmless bacteria, are found.

If the water be kept perfectly undisturbed, unoxygenated, and at a comparatively high temperature, these water-organisms increase in number at a very great rate. It has been found, as a result of numerous bacteriological examinations by various observers, that, if in a single cubic centimetre of any specimen of freshly-drawn water, 200 bacteria are found at the first examination, by the end of twenty-four hours the number may have risen to 5,000, and the end of a second twenty-four hours to 20,000, and twenty-four hours later the multiplication has become so rapid and has gone so far that they are no longer countable. After a short time this multiplication ceases until the water is re-oxygenated. If, however, water be taken from a much deeper

layer, micro-organisms are found to be almost, or entirely, absent, and not only micro-organisms, but organic matter, which has not been washed down to such a depth as that from which this water has been obtained. There are cases, however, of deep wells and springs, in which, although micro-organisms are practically absent, organic matter is still present in appreciable quantities. It is evident, then, that the superficial layers of earth act not only as mechanical, but also as biological filters. The water, with its contained organic matter, passes through the surface layers, in which bacteria can grow, down to those layers in which there are no organisms, the organisms not passing down with the water, first because they are held back mechanically, the soil acting as a porous filter, by which even extremely minute solid particles are held back, but also because most of the bacteria being anaerobic cannot leave the surface with impunity, most of those that are carried down by the water dying off as their supply of oxygen is gradually removed; for, in consequence of the rapid oxidation that is going on at the surface, very little free oxygen is left for the use of bacteria even in comparatively superficial layers. The few organisms that can persist develop the anaerobic faculty and utilize the small quantity of oxidized material that has been converted into inorganic matter and used up by growing plants. This amount is small because the reduction of the small quantity that remains after the plants are satisfied is soon completed, and bacteria can no longer obtain any material for their nutrition. When these conditions are borne in mind, it becomes evident that such valuable information as to the character of any water and its suitability for domestic use may be derived from a bacteriological examination, it being understood that the mere number of organisms can convey little accurate information except in those cases where it is examined at once, and even in such cases the information obtained is not of prime importance. Quite recently you have had amost animated discussion on the action of biological filters. So important is this question, and such a prominent part is it destined to play in the future of sewage disposal, that the discussion extended, I believe, over three nights after the paper had been read, and much still remains to be said on this most important question. I should like at this stage to indicate that what takes place in the breaking down of organic matter in nature may also take place, under certain conditions, in artificially-prepared filters. The main factors in the process are essentially the same as those already described. In the process it is necessary (1) to get all solid matter into solution, (2) to supply as large a quantity of oxygen in as short a time as possible to this organic matter; (3) to attack the organic matter in solution by means of micro-organisms and to so break it up that the various elements of which this complex material is composed may be thrown into an unstable or nascent condition so that the oxygen present may have an opportunity of entering into combination and of forming what are called oxodized sub-

stances. It is evident from what we know of putrefactive processes that these changes may take place in two perfectly different ways. In the one case we have the oxidation taking place directly, all the nascent substances being satisfied by the oxygen of the air and the splitting up of the organic matter being carried on by aerobic organism. In such a process of oxidation, which takes place in the porous soil well supplied with air and moisture, and also in water which is from time to time well saturated with oxygen, it will be found that little or no putrefactive odor is developed. The marsh gas, the sulphuretted hydrogen and other similar substances as they are set free rapidly combine with oxygen to form sulphuric acid, carbonic acid and water, and the nitrogenous substances in a similar fashion combining to form nitrous and nitric acids. In the soil these acids combine with the various basic substances, lime, magnesia and the like, are thus rapidly removed and the way is left clear for the formation of fresh batches of the same substances. In anaerobic putrefaction, on the other hand, the process does not go in this unobtrusive fashion, the anaerobic organisms having, as it were, to wrest their oxygen from the organic molecules because there is no free oxygen present, set up a much greater disturbance and the products of the decomposition such as sulphuretted hydrogen, marsh gas and ammonia, are thrown off in an unoxodized condition and in the free form (i. e., they are no longer in a nascent condition) they remain comparatively stable, and give rise to the putrefactive odors so characteristic of rapid anaerobic putrefaction.

"THE BLACKWALL TUNNEL."

By David Hay, M. Inst. C. E., and Maurice Fitzmaurice, B. E., M. Inst. C. E.

(*Abstract from Proceedings Institution of Civil Engineer [England] Vol. CXXX, 1897.*)

"DRIVING THE TUNNEL."

As it was of the greatest importance that the shield should be started to work with as little delay as possible, it was decided to erect it on the surface and lower it down No. 4 shaft as soon as the water-tight floor at the bottom should be completed. The weight of the shield without the hydraulic rams, etc., was about 220 tons, and it was decided to float it down; it was therefore built in a dry dock, forming part of the cut-and-cover trench adjoining the shaft. The ends were close planked and calked upon completion, and on a portion of the side of the shaft next the trench being removed, the shaft and trench were filled with water. The shield floated on the depth of water in the trench reaching about 17 feet; it was then towed into the shaft, and, as the water was pumped out, it sank until it reached the timber cradle previously prepared for it at the bottom.

After the shield had been placed in the tunnel opening of No. 4 cassion (in which cast iron guides had been bolted to ensure

true line and level being followed) a portion of the cast-iron lining extending to the other side of the shaft, was temporarily built up behind the shield to form an abutment for the hydraulic rams in driving the shield forward. It now became necessary to remove the plug from the tunnel opening; in doing so a commencement was made at the bottom, and as the girders carrying the bottom outside plates were removed the latter were temporarily strutted to the shield. Clay, chiefly in bags, was then built against the plates to support the face when they should be taken out. The second row of plates being similarly dealt with, a sufficient height was obtained to draw out the bottom row by means of a tackle or union screw; the same process was continued with the other plates until the whole of the plug was removed and replaced by a wall of clay, through which the shield was driven into the face beyond. This method of removing the plug refers more particularly to that adopted in gravel, etc.; when the face consisted of clay such extreme care was not necessary. The ground in front of the plug was sometimes grouted with cement before the plug was removed. The strata on starting from No. 4 shaft consisted of 1 foot of sand at the bottom overlaid by 25 feet of London clay with about 1 foot of ballast showing at the top. The latter, as previously stated, had been drained to a large extent by the pumps for the adjacent "cut-and-cover" work, and, as it was kown that on account of the gradient of the tunnel the ballast would soon disappear, it was decided not to use compressed air at the outset, but to drive a top heading to deal with the gravel and water. The water was strongly impregnated with creosote, oil, etc., from a tar distillery above, and considerable pain and inconvenience was felt by the men through inflamed eyes, and burnt hands and arms; this trouble, however, passed away as soon as the clay was sufficiently thick to cut the water off, after which the top heading was discontinued.

At first progress was somewhat slow, only 125 feet being driven in the first two months, but after the gravel disappeared and the top heading was discontinued, better progress was made, an average length of 25 feet being completed per week. An accident, however, soon after happened to the shield which caused some delay. At the base of the London clay, and in the sand immediately below it, large pieces of rock were embedded and considerable damage was caused to the cutting-edge by driving against them. This was first discovered after fifty-four rings had been erected, and, although great care was exercised in clearing the excavation in front of the up-turned part of the cutting-edge, the damage continued to increase, and, after another twenty-six rings had been erected, the shield was found to be unworkable. As it was not practicable to repair it in its then position, it was decided to construct a concrete cradle for it to slide upon. A timbered heading, 10 feet wide, was therefore driven and kept about 50 feet in advance of the shield, so that the concrete should have time to become hard before the shield came upon it. During the driving

of this heading trouble was again experienced from water in the ballast above finding its way through cracks in the clay, and the top heading was accordingly recommenced, so as to intercept the water and carry it through the shield. This method of working was continued until No. 3 shaft was reached, where the repairs to the shield were effected.

Until about 490 feet had been driven towards No. 3 shaft no great quantity of water was met with, but at that point a large volume suddenly broke into the bottom heading. Considerable difficulty was then being experienced in sinking No. 3 shaft, and the water which broke into the heading undoubtedly came from the ballast, and found its way either down the side of the shaft or through the cracks in the clay which had been caused by the numerous blows. As the shield was then only 67 feet from the shaft (the bottom of which was to be 15 feet below the invert of the tunnel) it was deemed prudent to suspend any further tunnelling operations until the shaft was sunk to its full depth. Meanwhile No. 1 bulkhead was built. It was constructed of concrete 12½ feet thick, having two locks at the level of the temporary tramway, fitted with rubber-faced doors. Two sets of outlet and inlet-cocks were provided, one, 2½ inches in diameter, for use when the locks contained materials only, and the other, 1½ inch in diameter, when men were passing through. The various pipes for compressed air, hydraulic pressure, blow-out pipes, etc., were built in as shown. The inner, or pressure, side of the bulkhead was rendered with cement, and any small spaces between the brickwork and the tunnelling, caused by settlement, were grouted up through pipes built in for the purpose, and by these means no difficulty was found in making the wall air-tight. In the three bulkheads which were afterwards constructed for other portions of the work, brickwork was substituted for concrete as being more easily removable, and a smaller lock, 3 feet wide, called an emergency lock, built in near the top of the tunnel, was added. No. 3 shaft having been sunk to its full depth, tunnelling operations were resumed as soon as the bulkhead was completed, the remaining length of tunnel from this point to the shaft being driven under compressed air.

A fire which occurred in the top heading on this portion of the work caused considerable anxiety. It was feared that the escaping compressed air might carry the flames through the ground saturated with very inflammable material to the distillery above, in which case a serious conflagration would have resulted. Happily a good supply of water was at hand, and the fire was extinguished before any such accident happened.

IRON AND STEEL PLATES AND FORGINGS USED IN SHIP-BUILDING COMPARED AND CONTRASTED.

By M. W. Aisbitt.

(From the Iron and Coal Trade Review [England] Feb. 18, 1898.)

At a meeting of the South Staffordshire Institute of Iron and Steel Works Managers held last Saturday, Mr. J. W. Hall (president) in the chair, a paper was read by Mr. M. W. Aisbitt (Cardiff) with the above title. He remarked that the relative positions of iron and steel as regards plates, angles, and other sections used in shipbuilding at the present day, as compared with twenty years ago, were entirely reversed. In 1878, 90 per cent of the total material used was iron, whereas at the present time 90 per cent of the total material used was steel. Since the introduction of iron plates there had never been instituted a regular system of testing them, as had been adopted in the case of steel plates; and this was much to be regretted, as, owing to the steel plates from their first production having been invariably tested for tensile strength and elongation, they had proved more reliable. In order to induce shipbuilders and shipowners to adopt steel in the place of iron, the various registries for the classification of steamers and sailing vessels agreed to adopt a reduced scantling to the extent of 25 per cent in the case of steel plates. This, in the case of a large cargo steamer, carrying 4,000 tons of cargo, and requiring 1,200 tons of iron material as against 900 tons of steel, was naturally a matter of serious moment to shipowners, as it was not merely the saving of 300 tons of iron, at so much per ton, but an additional carrying capacity of 300 tons to the steel steamer on the same draft, power, expense, etc. Hence they would readily see the reason why steel so quickly replaced iron. But after some years' experience it was found that this reduction of 25 per cent was considerably too much in many cases. Another reason for steel being preferred to iron, even in the case where it was introduced of the same scantling, was its ductility, and hence the possibility of bending it cold to any required shape. In the case of strandings, groundings, etc., he had generally found that of two given vessels which struck rocks, one steel and one iron, the iron one would cost considerably less to repair than the steel one. The iron, being of less tensile strength than steel, broke off short, locating the damage to a small area, and by so by breaking would generally allow the water to enter the vessel and keep her at rest until proper means, if possible, were adopted to float her On the other hand, the steel plates being of flexible nature, would not break but buckle between the various ribs, and probably allow the vessel to float about, striking the rocks over the whole length of her bottom before measures

could be taken to prevent her from doing so. Steel had the advantage over iron in being to a great extent homogeneous, and, in the case of oil steamers, more impervious to the penetrating effects of petroleum oil. Also, beyond the great advantage of ductility in working, it was found possible to produce plates and angles of a much larger section and dimensions than ever thought possible before. This added to the strength of a vessel by dispensing with a large number of butts or joints, and also decreased the cost by the less number of rivets, in some instances amounting to many thousands. His own impression was that a combination of steel and iron would be most advantageous for shipbuilding purposes, as the reduction previously spoken of namely, 25 per cent, was rapidly disappearing; and, considering the extra labor that the material of a cargo steamship had now to withstand as against that of one built, say, fifteen years since, amounting to about 20 per cent of the actual deadweight carrying capacity, this decrease was likely to proceed still further. The paper was illustrated by lantern views.

In the discussion which followed, the Chairman said that district could claim some distinction in connection with the history of modern shipbuilding, seeing that the first iron boat was made at Bradley, near Bilston, by John Wilkinson. At the present time the district supplied large quantities of material to shipyards, and about half the anchors and cables of the world. The mysterious fractures in steel of which they used to hear a good deal were traced to the fact that it had been manipulated by men accustomed to use iron. Under existing circumstances he thought the registries acted wisely in limiting the tensile strength of the material. The time was coming when in this country the use of higher-tensile steel for shipbuilding would be inevitable, and when the same system of building in position as was adopted in the case of boilers and bridges would be employed. High-carbon steel was coming to the front very rapidly, and the British Admiralty were specifying considerably higher strengths for their forgings and castings than they did years ago. Mr. T. Turner said the ideal construction in shipbuilding, as in boiler or bridge construction, would be to use material of all one kind. If every part of the ship was made of the same material of the same tensile strength, the difficulties of elongation and unequal expansion would be prevented. Mr. Le Neve Foster thought there should be the same rigid tests for steel as for iron. Mr. Ashton was of opinion that the failure of iron for shipbuilding was principally due to bad workmanship in the manufacture, and that if a proper list of tests were laid down the iron manufacturers could produce plates, both in the matter of homogeneousness and tensile strength, to meet all the requirements equally as well as steel.

THE TESTING OF MATERIALS USED IN CONSTRUCTION.

By W. C. POPPLEWELL, M. Sc., Assoc. M. Inst. C. E.

(From the "Mechanical Engineer," England, Feb. [illegible])

In all engineering works, whether they be of masonry, concrete, or metal, the question of strength is one of the most important which has to be considered; and where any material is to be so placed in a structure as to have to withstand considerable stress, some previous knowledge of the strength properties of this material must be within the reach of the engineer who contemplates its use.

In every engineering structure there are two distinct points with regard to its strength which must be aimed at. These are that, in the first place, the structure must be of ample strength to withstand any and all loads to which it may be subjected without permanent injury to its parts; and, secondly, that there should be no more material employed in any one part than is sufficient to ensure the fulfilment of the first condition. The chief reason for this latter condition is sufficiently obvious—it is simply a question of cost. But, apart from pounds, shillings, and pence, it is obvious that it would be an unwarrantable waste of valuable material to introduce any such beyond that which is necessary to ensure safety and efficiency, and, further, it is in many instances advisable to reduce the weight of a structure as far as possible, so as to thereby lessen the stresses due to the weight of the structure itself.

In the case of many engineering structures and works it is usual to apply some kind of test load after the completion of the structure, so as to provide a final check on the work before submitting it to its ordinary load. Thus, bridges are often tested in this manner, by putting upon them loads greatly in excess of those to which they may be expected to be subjected in daily use. Again, boilers are treated in a somewhat similar manner, by applying internal hydraulic pressure double, or more than double, the intended working pressure of the steam. There are, however, many structures which cannot be put to these final tests, owing to the nature of their load and the position of the structures themselves. Examples of such are to be found in roofs and bridges subject to wind pressures. But, even if it were possible to apply these after tests in all cases, it would be preposterous to construct a great and costly work entirely by "rule of thumb," and trust to luck that it would be strong enough to withstand the loads which might be applied to it.

Some previous knowledge, both of the loads to which each part of a structure may be expected to have to withstand and of the strength of the materials forming these parts, is absolutely necessary. In former times, before such knowledge existed of

the strength of the various materials of construction as is now the case, an engineer had to rely to a great extent on his own or other people's experience, and on his own judgment and instinct for the dimensions of the parts of his structures. Such a plan is of necessity still followed out to a great extent, especially in the case of small and unimportant parts, and also very often in timber structures. It is not an uncommon thing in drawing offices to see a draughtsman vary a dimension several times until he thinks "it looks right." This is perfectly legitimate and allowable in many cases, and is, indeed, necessary in such cases, for instance, as the frames of machines and other structures subjected to a great variety of indeterminate stresses, or to very slight stresses, where stiffness alone is necessary. But in large and important structures and pieces of machinery a certain definite plan must be, and nearly always is, followed.

In the first place, the engineer must know what loads his projected structure will have to sustain as a whole, what part of these are live loads, what part dead loads, and if any shocks are to be expected, and of what magnitude.

Secondly, knowing what the loads upon his structure are to be, he must next be able to calculate what will be the effect of these loads in producing stresses in the several parts of the structure, what are the magnitudes of these stresses, and what their nature; that is, whether the stresses are those of tension, compression, bending, or torsion.

Thirdly and lastly, he must have an intimate knowledge of the properties of the materials he intends to make use of, so as to be properly guided in determining the shape and dimensions of all the parts.

Of these three divisions the first entirely depends upon the knowledge which the engineer may have as to the conditions pertaining to the particular case in question; the second requires calculations depending upon the principles of mechanics, and may be performed by simple arithmetical or algebraic methods, or the problem may be attacked graphically. When these two first conditions have been determined, the last step in the design of the structure may be taken, that is, knowing the stress which may be expected to act on each part, both as to its nature and magnitude, and also knowing what materials are to be used, the engineer can at once proceed to ascertain the form and dimensions of these parts, provided he is fully acquainted, or has some means of becoming acquainted, with the strength properties of the materials. It is towards the fulfilment of this last mentioned condition that the "testing of materials" is undertaken.

For such a case as we have just considered, it is usual to test several small samples of the material to be employed, as in the case of a strip of steel cut from a boiler plate, on the assumption that the whole of the material is uniform and similar in its properties to the specimens tested, or, as in the case of a chain or rope, to subject an actual piece of the work itself to the test.

Such tests have been called "commercial tests," and may be either specially made in connection with the structure in question, or have been previously made on some samples of similar material. Besides tests of materials carried out for purely commercial and constructive purposes, there is a great deal of work being done at the present time, and has been done in the past, of a more refined and scientific character, with the intention, in most instances, of elucidating the more hidden and complex phenomena displayed by materials under various stresses and under different conditions of stress. Such research has been going on for many years, and is going on most actively at the present time. The knowledge obtained in this way is to a great extent permanent, and though, as time goes on more facts are constantly being unearthed with regard to the strength properties of materials, still these new facts are not, as a rule, such as to render unimportant the knowledge already gained, although it is certainly so in some cases. The value of this scientific or research testing may not be at once apparent, but every test and experiment made in this way is going to help to build up a more complete knowledge of the mechanical properties of materials.

There is another branch of testing that comprises within its limits both those already mentioned, namely, the testing carried on for purely educational purposes. Most of the colleges, or departments of colleges, devoted to the scientific education of engineering students possess some kind of a testing laboratory. Here, in these laboratories, the students are taught by personal instruction and actual experience to make tests of various materials, and in this way they are not only enabled to learn the details of the appliances used and the methods and systems employed, but their faculties of observation are called into play, and the properties of the materials they are dealing with are brought home to them in a manner not possible by mere description and the study of books. The number and completeness of the laboratories at technical schools and colleges is increasing year by year, and this is as it should be, because no branch of the scientific education of a young engineer is of greater help to him in after life than the time spent in laboratory work.

In the following chapters it will be the aim of the author not only to describe the various testing appliances and methods as used in purely commercial work, but, at the same time, to make these descriptions applicable to the work of an engineering student.

It has been stated that testing can, according to the apparatus and methods employed, be divided into *commercial* and *scientific* testing. These two are not necessarily quite distinct and apart, in many cases they overlap, but, generally speaking, the methods of commercial testing are more crude and the measuring appliances used not of so refined and delicate a character as many of those used in purely research testing, which partakes more of the nature of physical laboratory work. In commercial testing cer-

tain standards are usually fixed by purchasers of materials and by certain competent authorities, such as the Board of Trade and Lloyd's, and in the tests to which they are subjected the specimens are expected to exhibit such properties as are required to comply with the standards and regulations laid down. In making a commercial test, therefore, it is necessary to know what properties must be especially observed, so that it may be determined whether the tests do satisfy the requirements, and then to apply such, and only such, tests as may be needful for this purpose.

In scientific testing the case is different. The observations in a test are generally greater in number, more accurately made with apparatus of greater precision, enabling the observer to see more deeply into the phenomena exhibited during the tests.

All testing requires a considerable amount of skill, experience, and sound judgment in its execution, and to these should be added some knowledge of mechanics, so far as the "strength of materials" is concerned. System and order should be rigidly adhered to, both in the carrying out of tests and in the manipulation and presentation of the results. Every detail should be most carefully watched and attended to, as one mistake may render useless a test or even a whole series of tests. Nothing is of more importance than a correct idea of perspective so far as accuracy is concerned, and a clear knowledge of the necessary limits of accuracy to be aimed at, and which are possible in the various kinds of work undertaken, should be most carefully cultivated Useless attempts at extreme accuracy, where extreme accuracy is neither necessary nor possible of attainment, are always absurd, and in some cases actually mischievous.

The variety of material which is tested, or capable of being tested, is very great.

At the present day most engineering structures, whose design is governed by considerations of strength, are constructed of either iron or steel. These metals have asserted their preeminence in such work by reason of their combining the advantages of cheapness, strength and durability to an extent not found to exist in the case of any other material. The kinds of structures built of iron and steel are very numerous. In addition to the bulk of machinery used for purposes of manufacture, the engines which give the motive power to this machinery, and the shafting and gearing which serve to transmit the power from the engines to the machinery, in addition to their use in formation of structures such as these, iron and steel are greatly used for what, in one sense, are more important works. By these are meant structures whose collapse or failure would endanger human life. Of course, this possibility exists in the case of most machinery of any size, but it is especially evident in such structures as bridges, boilers, railway appliances and steamships. In most of these strength is of the first importance, although considerations of form do in most cases affect the design. In addition to iron and steel there are other metals in use for engineering purposes,

although in these, other qualities rather than strength, render their use desirable. Such are copper, brass, gun metal, tin, zinc, lead, aluminum, and various anti-friction alloys. Of these there are several where considerations of strength do enter largely into their use. For instance, copper is used for boiler fire-boxes, stays, steam pipes, and for overhead electrical conductors, where it has to withstand great tensile loads; gun metal also is often used in machine and engine parts where it has to undergo considerable tension or compression. The increasing use of aluminum and its alloys makes it necessary for its strength properties to be known; and lastly a knowledge of the compressive strength of anti-friction alloys in bearings is often needed.

Timber is used to a great extent in constructive work, especially for temporary work. It is, however, too uncertain a material to allow structural parts to be designed with the same certainty that exists in the case of the metals, without the use of a large margin of safety. Still, tests of timber, although approximate in character, are often necessary and useful, and give reliable information when properly carried out and judiciously applied.

Last among the materials of construction which are tested are those substances which are employed in works of masonry and those of a like nature, chief among them being the different kinds of natural stone, bricks and terra-cotta, cements and limes, and these combined with other substances to form the various kinds of concrete which are used. So much depends on the strength and reliability of these, which are very largely used in the case of buildings, retaining walls, bridges, foundations, and harbor works, and so great is the variation in quality of apparently similar substances, that they present a large field for testing operations.

It will be clear from what has been said that the variety of substances which are subjected, or may be subjected, to tests is very great, and not only do these many substances used in constuctive work present many differences in their qualities and behavior under test, but there are many ways in which any given substance may be tested. Take for example mild steel. It may be used for boiler plates, when its behavior under a tensile test becomes important; if for the rivets of the same boiler, its shearing strength should be known, it may be used in the manufacture of pillars or struts, when its compressive strength is required to be known, or, it may be that the steel is required to construct a propeller shaft of, when its properties under a test in torsion are necessary.

And so it is all through. As a rule, it is not sufficient to know the general strength properties of a substance, but the properties which exhibit themselves under special circumstances, and when made of special forms, must also be known, and the tests applied should be always judiciously selected and carried out, so that the actual conditions of use shall be as nearly as possible satisfied.

PRODUCTION OF POWER BY GAS PRODUCERS AND ITS RATIONAL DISTRIBUTION.

(*From The Colliery Guardian.* [*London, England*], *February 11, 1898.*)

Power may be obtained in a simple manner by the producer gas apparatus, a thick layer of fuel being charged into a cylindrical generator, and a steam jet introducing under the grate the air required, previously heated, observed Herr Johann Korting at the Hanover Miners' Congress. The gases thus obtained, which are rich in hydrogen and carbonic oxide, are cooled and washed before entering a receiver, that chiefly serves as regulator, the most suitable classes of fuel being slighly bituminous coals, such as anthracitous coal, anthracite, coke and charcoal. The utilization of 82 per cent of the combustible matters in the Korting power-gas constitutes a very favorable result, even when the gas used for raising the steam necessary for insufflation be taken into account.

Gas engines of 100 horse power consume 2 cubic metres (70 cubic feet) of power gas, corresponding with a useful effect of 23.6 per cent.; those of 50 horse power, 2½ cubic metres (88 cubic feet), corresponding with 18.7 per cent; and those of 10 horse power, 3½ cubic metres (123 cubic feet), with 13.3 per cent of useful effect. Deducting from the above percentages 20 per cent for loss in production and what corresponds with raising steam, they become respectively 19, 13.5 and 11 per cent.—far more favorable than those in the case of steam.

The old method of transmitting power by belt and pulley, or spur gear, entails for each transmission a loss of about 15 per cent, so that with four successive transmissions the loss amounts to about 50 per cent; and in many cases only 25 per cent of the power is utilized, rope gear being subject to similar conditions. Transmission of power by compressed air is costly, but in mines this high cost is compensated by the advantages obtained. While the advantages of electromotors are generally recognized, the total loss by this method, including that of the conductors, is about 30 per cent, which is increased to 40 per cent in small installations.

When power has to be transmitted to separate groups of motors or machines by means of steam, there are the disadvantages of condensation and leakage in the pipes; and, if a 500 horse steam engine be superseded by ten 50 horse engines, double the coal will be burnt, entailing a loss of 50 per cent. By the use of gas engines, on the contrary, the above-named disadvantages are avoided, and the use of small gas engines is comparatively less costly than that of small steam engines as regards the consumption. If in a 500 horse gas engine nearly 0.45 kilog. (1 lb.) of fuel be burnt per horse power per hour, ten 50

horse gas engines will consume 0.55 kilog. (1.2 lb.) of fuel per hour, showing a loss of only about 20 per cent.

The distribution of power by gas engines is, therefore, the most economical, and the plant is not more costly than of an electric central station for power. In many cases it is advisable to actuate the various groups of motors and machines by gas engines, and to subdivide the power by electricity.

THE STORAGE OF EXPLOSIVES.

By Robert Hunter.

(From The Colliery Guardian, (London, England), February 11, 1898.)

One of the consequences of the Explosives in Coal Mines Order 1897, is that proprietors of collieries, who until lately allowed their miners and contractors to buy blasting powder and other explosives from local dealers, have now to make provision for supplying to their own workmen the permitted explosives which they adopt for use in their mines. In districts where blasting powder was used almost exclusively, many grocers, ironmongers, and co-operative stores had their premises registered and, according to facilities they possessed, could keep from 50 to 200 lbs. of blasting powder, which they retailed to miners in quantities as required, and such sales formed an important item in their turnover. But as the Orders in Council, under the Explosives Act 1875, do not permit dealers to keep more than 15 lbs. of any permitted explosive, unless they have specially constructed buildings in which 60 lbs. may be kept, it is quite impossible for one in a hundred of such dealers to supply the wants of even a small mining district. More especially is this the case since all permitted explosives must be fired with a detonator or electric detonator fuse, as these require to be stored apart from other explosives and so reduce the quantity of the latter, which may be kept on registered permises to, say, 10 lbs. and a small stock of detonators.

Colliery proprietors must therefore erect suitable buildings in which to store explosives, and fortunately there are few coal mines so situated that a site for such a building cannot be easily got.

Anyone proposing to erect a store should endeavor to find a site which will entitle it to be licensed for the maximum quantity, as although a small one may suffice for present needs, these may expand and involve the erection of a larger store at a later date, the necessity for which might have been obviated by a little foresight. It is also important to select a site alongside, or not distant from, a private road, as the cost of making a good road is considerable and keeping it in order costs something yearly, even when there is little traffic on it. The quantity of explosives which may be kept in a store varies according to the distance which the building is from what are known as "protected works," licenses

being granted under four divisions, A 300 lbs., B 1,000 lbs., C 2,000 lbs., and D 4,000 lbs. The more important "protected works" are these in the following table, and in the columns headed A, B, C and D are shown the number of yards an explosives store must be distant from them, to qualify it for 300, 1,000, 2,000 or 4,000 lbs. license.

	A.	B.	C.	D.
From a dwelling house, shop, room, mineral or private railway, tramway, workshop, places where explosives are kept, furnace, kiln, or fire ....yards	50	100	150	200
If the licenses occupies these protected works or the premises on which they are situated, or if the occupier gives his consent in writing, the distances are reduced to........................yards	25	50	75	100
Also from any public road or path, promenade, canal, dock, river, or sea-wall, pier or reservoir...yards	25	50	75	100
Also from any public railway, factory, church, college, school, court, market, theatre, hospital, or public building..................yards	50	100	150	200
Also from any factory or magazine belonging to Government.. yards	440	880	1320	1760
And from any palace or house of residence of her Majesty, her heirs or successors..............miles	2	2	2	2

The building must be substantially constructed of brick, stone or concrete, or excavated in solid rock, earth, or mine refuse, not liable to ignition. It would not be permissible to have bare brick or stone walls inside. A coating of cement on the inside walls is not much better, as, unless great care is exercised, the cement is apt to scale off and become a source of danger. If the cement is painted it may keep in fairly good condition, but the best plan of all is to have the building lined with wood and have a wood floor, all fastened with copper, brass, or zinc nails, or iron nails countersunk and puttied, and apply two or more coats of paint or varnish to walls and ceiling. If the store is to be licensed for more than 300 lbs., double doors are advisable, both of which should open outwards, be fitted with strong locks, and with hinges inaccessible from the outside.

It is very necessary that the building will be ventilated, as a store is generally in such a situation that it is exposed to sun and rain, and, unless free ingress and egress of air is provided for, many explosives will deteriorate in the moist atmosphere which such influences generate and maintain. The woodwork of the

store is also likely to rot and require frequent renewal. The ventilators should be so constructed that access cannot be obtained by them to the contents of the store, and that malicious persons cannot insert combustibles through them which might cause fire or explosion. Precautions must also be taken to prevent water getting into the store, as it has injurious effects on every explosive.

Having supplied plans and selected sites for many such building in England, Scotland and Ireland, which have met with the approval of inspectors of explosives, the writer thinks that the accompanying sets of plans and specifications may be of service to colliery proprietors, relieving them from doubt as to what kind of building is required and possibly saving unnecessary expense.

SPECIFICATIONS OF THE SEVERAL WORKS REQUIRED IN THE ERECTION OF A STORE FOR EXPLOSIVES.

Foundation. The site of the building to be levelled, and the subsoil sufficiently removed in order that a firm bottom be obtained, and the foundation to consist of hard-burned bricks or rubble well grouted with mortar.

Walls. The walls to be of the best hard-burned bricks 9 inches thick, and every fifth course to be headers. Gable ends to be carried up to top of roof and circled as shown on plan, and the outside walls to be neatly pointed.

Roof. The roof to be covered with galvanized corrugated iron 22 B. W. G., screwed to purlins, which are to be laid from gable to gable as shown in plans, and bedded in cement at gables and wall plates, and joints filled with white lead, also screw or rivet holes.

Door Frames. Door frame to be 9 in. by 2 in., fastened to dooks built into wall and lintel 9 in. by 4½ in.

Doors. Outside door to be 6 ft. 1 in. by 3 ft. by 2 in. and inside 6 ft. by 2 ft. 8 in. by 1½ in., framed and lined, and moveable block inside inner door 9 in. by 2 in. with fillets on each side so that it can easily be lifted out.

Flooring. Sleeper joists to be 6 in. by 2 in., and flooring 1¼ in. tongued and grooved.

Lining. The inside walls and ceiling to be lined with ⅝ in. plain white lining, fastened to fillets as shown in plans, but not touching walls, and with breaks in fillets at intervals to allow air to pass all around, and nailed to wall plates at top and flooring at bottom, with a fillet at top and botton on all four sides.

Lightning Conductor. Lightning conductor to be of ¾ in. round iron, terminating 4 ft. above roof in three points, nailed against wall by iron holdfasts and carried 6 ft. into the ground at an angle of 45 degrees away from the building.

Ventilators. One cast iron ventilating air brick 9 in. by 4½ in. to be inserted on each side, with a dwarf wall 18 in. long opposite each, and a slate or slab same length on top just under flooring, all as shown in plans.

Locks. All locks, hinges, and nails where exposed, to be of brass or copper, or counter-sunk and puttied.

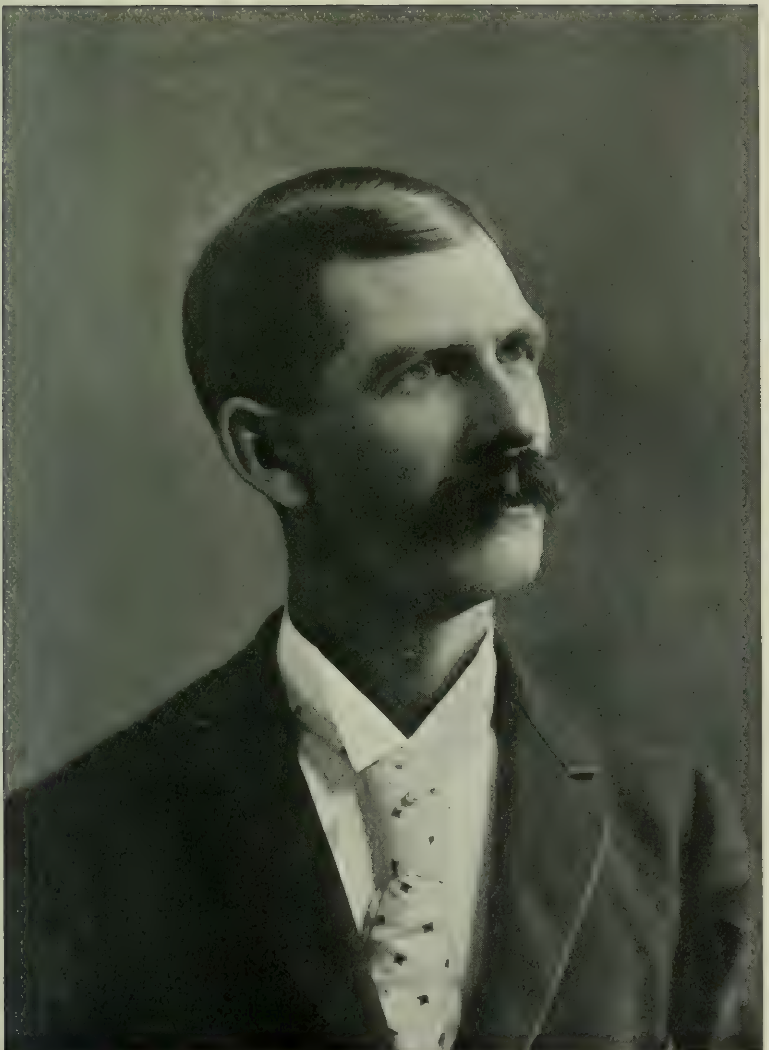
Woodwork. Outer and inner doors with their frames to be of best red pine, and the remainder of woodwork of white pine. All to be thoroughly well seasoned and perfectly free from knots, shakes or bluewood.

Painting. Outside door and all exposed woodwork to receive three coats of good oil paint.

EDWIN G. NOURSE.

A MEMOIR.

Mr. Edwin G. Nourse, whose death by accident occurred at Davenport, Ia., on December 8, 1897, was the son of Mr. and Mrs. Horatio G. Nourse, and was born at Peoria, Ill., Feb. 13, 1849. At the age of three years, the family moved to Moline, Ill., where Mr. Nourse attended the public schools and graduated from the Moline High School in 1867. In the fall of 1869 he entered Griswold College, Davenport, Ia., where he continued his studies in fitting himself for the engineering profession until June, 1871. His first field work after leaving college was with the United States Government in the spring of 1872, under Col. Macomb, on surveys at the Rock Island Rapids, on the Minnesota River, and at the Kingston Lock, on the Illinois River, leaving the government service in the latter part of 1874. In the spring of 1875 he engaged himself with the Chicago Milwaukee & St. Paul Railway Company and remained with that Company until the early part of 1883. During this period Mr. Nourse had charge of location and construction of several important pieces of work, among which was the construction of their double track bridge across the Mississippi River between St. Paul and Minneapolis, the Niobrara extension in Nebraska and the Marian and Council Bluffs extension, 260 miles in length. His resignation from this Company in 1883 was for the purpose of accepting a position of chief engineer for the Chicago, Evanston & Lake Superior Railway Company, a terminal property afterward acquired by the Chicago, Milwaukee & St. Paul Railway Company, and which included the construction of a double main track from this city to Evanston, where the work stopped. It was during the construction of this line that distinguished him not only as a skilled engineer, but a man of rare executive ability as well, for riots between the railroad laborers and the citizens living in the vicinity through which the road was constructed were not infrequent. Early in the year 1887 he resigned his position as chief engineer of the Chicago, Evanston & Lake Superior Railway Company to accept position of assistant engineer with the Atchison, Topeka & Santa Fe Railroad Company in charge of the construction of their terminal system, and later on as resident engineer of all lines east of the Missouri River for the same company. His services with the Santa Fe ended in the spring of 1890, when he became the consulting engineer for the Northwestern Construction Company, which position he resigned in January, 1891, to accept position as assistant engineer in charge of the construction of the World's Fair terminal system. His several years experience in the construction of railway terminals fitted him eminently for this work and many of us who viewed the terminal station with its net work of



EDWIN G. NOURSE.

tracks constructed in so short a space of time and noted for the number of trains taken care of, will concede that he had the inherent privilege to effect a deep pride in his crowning success as a very efficient railway terminal engineer.

At the expiration of his services with the World's Fair, in January, 1894, he formed a co-partnership with Mr. Patrick Haley, and laid the track for the Metropolitan West Side Elevated Railroad Company, which is conceded to be the finest piece of elevated track work in this country. On October 7, of last year, Mr. Nourse became the assistant engineer for the Davenport and Rock Island Construction Company, where he had charge of the construction of a railroad bridge across the Mississippi river, between Davenport and Rock Island, and it was while in this capacity that he met his untimely death. In connection with this a communication to Secretary Litten from Chief Engineer C. F. Loweth, which is given herewith, will explain the manner in which Mr. Nourse met his death.

OFFICE OF DAVENPORT AND ROCK ISLAND CONSTRUCTION CO.,
301 West Third Street,
DAVENPORT, Ia., Jan. 15, 1898.

Mr. Nelson L. Litten, Secretary, Chicago, Ill.

DEAR SIR—Complying with your request of December 23, I give you the following information concerning the accidental death of Mr. E. G. Nourse, C. E.

Mr. Nourse was assistant engineer for this company in connection with the building of a railroad bridge across the Mississippi river, between this city and Rock Island, and had been to work about two months previous to his death. He was living in Moline, and on the morning of December 8, 1897, his wife brought him from their home to the bridge site in west Rock Island, and leaving him, drove to her home; less than fifteen minutes afterward he was killed, and immediately on her return home his wife was advised of his death and her loss.

The accident occurred at a small viaduct abutment in the Rock Island approach to the bridge, the stone for this was being brought to the work on wagons from the railroad yards a short distance away; a stone had just been lifted off of the wagon, and was being held in the derrick at a height of not more than five or six feet above the ground, when one of the guys slipped from its fastening and the derrick fell, the mast striking Mr. Nourse on the head, and killing him almost instantly.

The funeral occurred on the morning of the 10th, the honorary pall-bearers being civil engineers from this vicinity.

Mr. Nourse left an aged father, and a wife to whom he had been married less than a year. Moline was the home of his boyhood, though he had not resided there for a number of years prior to his return, about the first of October, 1897.

If I can be of further service, please command me.

Yours truly,

(Signed) CHAS. F. LOWETH.

Mr. Nourse lived through life just as his father and mother taught him to live, thoroughly conscientious and upright. Whatever he undertook he executed it with thoroughness and with a determination that knew no failure. It was this trait, perhaps, although tender at heart, that made him very decided in his likes and dislikes. While he was always modest and unassuming, he could always be found in a jovial and witty mood and ready to crack a joke whenever opportunity offered.

The Chicago Tribune of December 9, 1897, says of him: "Mr. Nourse was one of the best known and most successful scientific engineers in the West. He gained particular distinction through his achievement in the designing of the railroad terminal entering the World's Fair grounds in Chicago. For many years he was chief engineer of the Chicago & Evanston railroad and was identified with the engineering department of the Milwaukee, Northwestern and Santa Fe systems. He was also prominently identified with the building of the bridge across the Mississippi at Minneapolis. He was born in Moline and was 49 years of age.

Mr. Nourse was elected an active member of this society March 6, 1889, and served efficiently as treasurer of the society during 1893.

As has been truly said of other members of this society who have passed away, he needs no monument for identification.

Frank G. Ewald,
E. C. Shankland,
William Lee.

ABSTRACT OF MINUTES OF THE SOCIETY.

ANNUAL MEETING OF THE SOCIETY.

The Annual Meeting of the Society was held at the Technical Club, 230 So. Clark Street, Chicago, Tuesday evening, 4th of January, 1898. The meeting was called to order by President Thos. T. Johnston. The reading of the minutes of the previous meeting was dispensed with.

The Secretary read the report of the Judges of Election, viz :

JANUARY 4, 1898.

To the Western Society of Engineers :

We, the undersigned election judges appointed by the Board of Direction, having duly canvassed the vote cast for the election of officers for the year 1898, respectfully submit the following result:

Total number of votes received	132
Thrown out as irregular	3
Total number of votes counted	129
Cast for President, Alfred Noble	128
" First Vice-President, James J. Reynold	129
" Second Vice-President, A. V. Powell	128
" Treasurer, C. W. Melcher	129
" Trustee, Geo. P. Nichols	129

EDWARD WILMANN.
F. H. DAVIES.

REPORT OF TREASURER.

CHICAGO, January 4, 1898.

To the Board of Direction of the Western Society of Engineers :

GENTLEMEN—I respectfully submit herewith a summary report of the treasurer's accounts for the year 1897:

Table A, receipts for 1897.

Table B, expenditures for 1897.

As it may be of interest to the members the corresponding tables for 1896 are next given.

Table C, receipts for 1896.

Table D, expenditures for 1896.

Combining and condensing the tables somewhat, we have the following:

Net Receipts.	*1897*	*1896*
Back dues	$ 165 00	$ 147 50
Dues for current year	3,393 25	3,407 00
Dues for ensuing year	113 00	81 75
Entrance fees	395 00	390 00
Total	$4,066 25	$4,026 25
Net Expenditures.		
Journal	$ 85 62	$ 866 84
Services	2,070 75	1,956 56
General printing	273 55	199 65
Stationery and postage	380 06	332 48
Library	245 71	98 98
House expense	523 04	409 43
Lantern slides and sundries	13 20	60 77
Total	$3,591 93	$3,924 71

The difference in net cost of Journal for 1896 and 1897 is due to the fact that last year we had no back advertising dues to collect, while this year we have

TABLE A.

	Back Dues	Dues for Current Year	Future Dues	Entrance Fees	Journal Sub 1896	Journal Sub 1897	Journal Sub 1898	Adv to Dec 31 1896	Adv to Jul 1, 1897	Journal Sales	Rent	Stationary and Postage	General Printing	Library	Lantern Slides	Sundries	Total
January	47 50	112 50		95 00	2.00	60 00		514 00		15 60		41					[illegible]
February		339 50	8 00	50 00	24 00	70 00		169 00		19 25	16 00						695 75
March	40 00	285 00		60 00	21 70	45 30		84 00		15 80	32 00	60	3 50	2 20		23 00	613 10
April	15 00	478 75	15 00	35 00	8 00	11 75				16 00	16 00	1 40		95	6 60	20	604 65
May	27 50	135 00		30.00	10 85	13 75		123 00		3 50		80					344 40
June	15 00	160 00		30 00		9 75				2 80	8 00			50			226 05
July	20 00	295 00		30 00		40 00			140 50	1 00				20			526 70
August		62 50			4 00	32 00		12 00	349 50	4 60							464 60
September		85 00		30 00	2 00	4 00		25 00	138 00	5.60		70					290 30
October		130 00	7 50	10 00		20 00			48 00	4 35			8 50	3 00			231 35
November		152 50		15 00		2 00	1 75		54 00	1 50	26 70	1 06		2 15			256 66
December		157 50	82 50	15 00	2.00	33.00	1 75	6.00	118 00	17.90		.50				25	434 40
	165 00	3393 25	113 00	400 00	74 55	341 55	3 50	933 00	848 00	107 90	98 70	5 47	12 00	9.00	6 60	23 45	6 534 97
													Balance in Bank Jan 1st 1897.				563 42
															Total		7 0[illegible]8 39

TABLE B.

	Journal	Services	General Printing	Stationary & Postage	House Expense	Library	Entrance Fees	Sundries	Lantern Slides	Total
January	440 45	125 00	24 45	110.10	48 88	2 80	5 00	2 00		758 68
February	119 54	180 00	15 00	47 55	61 96			35		424 40
March	177 15	181 85	18 65	36 37	50 05	7 80		25		[illegible]72 12
April	621 83	177 25	84 70	34 01	50.15	3 00		30	28 80	1 000 04
May	35 76	160 50	4 80	15 20	48 72	17 41		25		282 64
June	253 41	168 90	21 50	22 70	48 95	68 70		30		584 46
July	4 90	150 80	8 20	23 54	44 46	27 80		20	6 60	266 30
August	307 43	150 90	80 70	32 33	57 07	39 00		1 05		668 48
September	61 95	166 10	1 75	6 80	41 75	10 00		20		288 55
October	259 51	186 25	7 40	16 15	42 99			35		512 65
November	14 19	188 85	13 80	21 88	47 41	5 40		2 35		293 88
December	88 00	234 55	4 60	18 90	79.35	72 80		25		508 46
	2394 12	2070 75	265 55	385 53	621 74	254 71	5 00	7 85	35 40	6 060 65
									Balance in Bank Dec 31st 1897	1 037 74
									(Notes on hand - - - 15 00)	
									Total	7 098 39

TABLE C.

	Back Dues	Dues for Current Year	Future Dues	Entrance Fees	Journal Sub	Adv Journal	Journal Sales	Rent	Stationary and Postage	General Printing	Library	Sundries	Pub Com		Total
JANUARY	70 00	957 50		40 00				8 00				.15			1075 65
FEBRUARY	10 00	297 50						16 00			30	58			324 38
MARCH	30 00	297 50		90 00	48 00		8 00	24 00							497 50
APRIL	10 00	455 00		15.00	33 75	36 00	16 00	8 00			2 00				575 75
MAY	10 00	282 50		10.00	6 00		1 00	48 00				60			358 10
JUNE		207 00	5 50	25.00	78 00	103 50	5 00								424 00
JULY		416 25	6 25	35.00	18.00	411 00	1 50	8 00							896 00
AUGUST	7 50	96 25		10.00	46 00	185 00		8 00							352 75
SEPTEMBER		80 00		10.00	73 00	234 00	1 50					10			398 60
OCTOBER		92 50		5.00	18 00	42 00	1 50	16 00					20 91		195 91
NOVEMBER		77 50	30 00	70 00	25 25	18.00	1 50		7 44						229 69
DECEMBER	10 00	147 50	40 00	80 00	9 50	151 50	46 30	32 00							516 80
	147 50	3407 00	81.75	390 00	355 50	1181 00	82 30	168.00	7.44		2 30	1.43	20.91		5845 13
														BALANCE IN BANK JAN 1ST 1897	656 08
														TOTAL	6501 21

TABLE D.

	Journal	Services	General Printing	Stationary & Postage	House Expense	Library	Entrance Fees	Sundries	Pub Com	Secretary	Furniture & Fixtures		Total
JANUARY		122 88	38 75	12 05	44 59	1 75		32 40	150 00				402 42
FEBRUARY	125 70	27 00	8 50	17.15	50.58			16 15					245 08
MARCH	843 68	198 32	1 50	9 35	54 51	1 55		10.35					1119 26
APRIL	22 25	257 83	8 75	53 78	46 50	2.75		2 15	69 00	50 00	144 20		657 21
MAY	56 90	155 83	9 30	26.22	49 26	27 48		15					325 14
JUNE	325 48	327 30	15 85	49 75	46 53	46 75		25					811 91
JULY	12 25	5 00	63 20		40 00			40					120 85
AUGUST	132 60	130 00	11 50	26 33	49 25	21 00		.15					370 83
SEPTEMBER		160 00	7.55	34.84	45 00								247 39
OCTOBER	350 38	166 00	9 15	31 17	42 75								599 40
NOVEMBER	280 06	170 00	14 35	45 43	44 75								554 59
DECEMBER	138 30	236 40	11 25	33 85	63 71			20					483 71
	2287 55	1956 56	199 65	339 92	577.43	101 28		62 20	219.00	50.00	144 20		5937 79
												CASH ON HAND DEC 31ST 1898.	563 42
												TOTAL	6501 21

collected $933 for advertising in the Journal of 1896. On the other hand, we have paid for six numbers of the Journal in 1897 as against four numbers in 1896.

Respectfully submitted,

E. GERBER, Treasurer.

The foregoing statement of the treasurer has been compared with the books of the secretary and found to agree. All expenditures have been properly vouchered.

HIERO B. HERR,
CHARLES L. STROBEL,
H. N. ELMER,
Auditing Committee.

January 4, 1898.

REPORT OF FINANCE COMMITTEE.

CHICAGO, January 3, 1898.

To the Board of Direction of the Western Society of Engineers:

GENTLEMEN: At the beginning of the year 1897 the Finance Committee of the previous year made a report, which is printed on page 104 of Vol. II., No. 1, of the Journal.

If we make a similar compilation for the year 1897, and place it beside that of 1896, we have the following table:

	1897	1896
Cash on hand	$1,022 74	$ 563 42
" in hands of Secretary	50 00	50 00
Unpaid dues	355 00	320 00
" Journal subscription	119 00	54 00
" Advertisements	1,110 00	1,172 00
" Room rent	13 35	
	$2,670 09	$2,159 42
Less future dues and subscriptions paid in advance	116 50	87 75
Assets	$2,553 59	$2,071 67
Estimated bills payable at end of year	793 93	1,053 16
Apparent net assets	$1,759 66	$1,018 51

We have, therefore, an apparent gain in our assets over those at the close of 1896 of $741.15.

In the above statement of accounts due the society there is not included the sum of $273.50 due for advertising and subscriptions to the Journal for the year 1896. These accounts, remaining unpaid after repeated efforts to collect them during the past twelve months, are a questionable asset, and, therefore, they have not been taken account of.

In the amount of bills payable is included the estimated cost of the December Journal. This is, perhaps, not yet a debt, but it is included to compare with the 1896 statement, where a similar item was included.

At the beginning of the year your committee prepared a budget of estimated receipts and expenditures. In May we were called upon to revise it. These budgets, with actual expenditures, are tabulated below.

Comparison of Finance Committee's budgets with actual receipts and expenditures for 1897:

Receipts.	January Budget.	May Budget.	Actual Receipts and Expenditures.
From resident members	$3,000	$2,870	
From non-resident members	840	880	
From rent of rooms	120	120	
Totals	$3,960	$3,870	$4,066 25

Expenditures.	January Budget.	May Budget.	Actual Receipts and Expenditures.
Stationery and postage	$ 300	$ 400	$ 380 06
General printing	200	300	273 55
Services	2,000	2,100	2,070 75
Journal deficit	400	200	85 62
Library	400	200	245 71
House expense	550	600	523 04
Sundries	50	50	13 20
Totals	$3,900	$3,850	$3,591 93

The budget of estimated receipts was made up on the basis of the full membership at the beginning of the year, the experience of 1896 indicating that an estimate of receipts on that basis would about equal the gross receipts from all sources. See Journal, Vol. II, No. 1, page 105. The basis seems to be reasonably well substantiated by this year's experience, as the difference between the January estimate and final results is very small.

The Journal has cost us $85.62, and as during the year six numbers were paid for the advertising due us at the beginning and end of the year were about the same, we may say that the above amount represents the actual cost for one average year. The Publication Committee are to be congratulated on the excellent results obtained.

As we have now a considerable balance on hand, we would recommend to the Board of Direction that a portion of the funds be deposited in some savings bank at interest, for such time as it can be spared.

Respectfully submitted,

E. Gerber,
J. F. Lewis,
T. L. Condron,
Finance Committee.

REPORT OF THE SECRETARY FOR THE YEAR 1898.

Chicago, January 1, 1898.

To the Board of Direction of the Western Society of Engineers:

Gentlemen—I have the honor to submit the following report:

At the annual meeting of the Society held Tuesday, the 5th of January, 1897, the records of this office showed a total membership on 31st December, 1896, of members, juniors and associates 411, viz.:

Resident Honorary Members	1	
Resident Members	272	
Resident Juniors	3	
Resident Associates	25	
Non-Resident Members	107	
Non-Resident Juniors	1	
Non-Resident Associates	2	— 411
Elected and qualified to 31st of December, 1897.		
Resident Members	28	
Resident Juniors	5	
Resident Associates	6	
Non-Resident Members	10	
Non-Resident Juniors	1	
Reinstated Resident Members	1	
Reinstated Non-Resident Members	1	— 52
		463
Losses.		
By death, Resident Members	2	
Resignation, Resident Members	11	
Resignation, Resident Juniors	1	
Resignation, Resident Associates	4	
Resignation, Non-Resident Members	6	

Delinquents of 1896.		
Resident Members	12	
Resident Associates	1	
Non-Resident Members	3—	40
		423

During the year one junior was transferred to the grade of member.

Total membership 31st of December, 1896	411
Total gains	52
	463
Total losses	40
Total membership 31st December, 1897	423
Classed as follows:	
Resident Honorary Members	1
Resident Members	263
Resident Juniors	5
Resident Associates	23
Non-Resident Members	122
Non-Resident Juniors	4
Non-Resident Associates	5
	423

During the year nineteen meetings were held; of these nine were in the Society rooms, nine at the Technical club, 230 S. Clark street, and one at Armour Institute of Technology.

LIST OF PAPERS AND DISCUSSIONS BEFORE THE SOCIETY.

20th January. "Mt. Wood and Top Mill Tunnels on Eastern Approach to Ohio River Bridge, Wheeling Bridge and Terminal Railway," by W. J. Yoder. Illustrated by lantern.

3d February. "Technical Education," a discussion on the occasion of the presence of the president, faculty and alumni of the Rensselaer Polytechnic Institute of Troy, N. Y.

18th February. "Erection of the New Draw Span of the Rock Island Bridge," by Ralph Modjeski. Illustrated by lantern slides.

3d March. "Deep Well Pumping," by E. E. Johnson, accompanied by written discussions by Thos. T. Johnston, A. F. Nagle, Charles L. Harrison, J. F. Lewis, D. W. Mead, Victor Windett, Charles W. Melcher, C. F. Loweth. Illustrated by lantern slides.

24th March. "Railway Ties in India," by Clement F. Street.

7th April. "The Britts Landing Cable Hoist and Quarry," by R. D. Seymour. Illustrated by lantern slides, and "Deflection of Wooden Stringers," by E. R. Shnable.

5th May. "Rope Transmission," by Staunton B. Peck. Illustrated by lantern slides.

26th May. Mr. C. G. Burton gave an X-ray talk with apparatus.

2d June. "Government Concrete Wing Dam at Rock Island, Ill.," by Lieut. Odus C. Horney, Corps of Engineers U. S. A.

7th July. "Limestone Screenings in Cement Mortar," by Prof. A. N. Talbot, and a written discussion by Alfred Noble and S. M. Rowe. Report of the committee upon the condition of the iron work in the old U. S. Postoffice and Custom House building in the city of Chicago.

21st July. "Causes of the Variable Efficiency of Steam Boilers and Their Influence on Tests," by F. G. Gasche.

4th August. "The Internal Hydrostatic Pressure in Masonry with Especial Reference to Masonry Dams," by A. E. Broenniman and H. H. Ross.

8th September. "Motocycles," a discussion prepared by Messrs. H. M. Brinckerhoff, L. L. Summers and Bion J. Arnold.

6th October. "The Excursion to the East," and a discussion on "Steel Forgings."

28th October. "Report of the Society's Trip to the East," by Isham Randolph, chairman Entertainment Committee. "Development of the Society's Extended Excursions," by Thos. T. Johnston. "Gliding Experiments," by Octave Chanute. Illustrated by lantern slides.

3d November. "What lines should be laid down as a guide to an engineering education?" a discussion

1st December. "Cements," a general discussion led by Thos. T. Johnston.

22d December. "The Restoration of the Artesian Water Supply at Savannah, Ga.," by Thos. T. Johnston.

Yours truly,
NELSON L. LITTEN, Secretary.

REPORT OF PUBLICATION COMMITTEE.

The Publication Committee for the year 1897 leaves the Journal to speak for itself. Its influence upon the library is evident upon inspection, particularly in the matter of exchanges. The rooms of the Society contain the best collection of current engineering literature to be found in Chicago. As in 1896, so in 1897, the Journal has stimulated the production of valuable papers by members of the Society.

Financially the Journal has been a success, as is evidenced by the following statement for the year:

REVENUE.

	Paid.	Unpaid.	Total.
Advertisements	$ 848.00	$1,110.00	
Subscriptions	330.05	119.00	
Sales	55.55	......	
	$1,233.60	$1,229.00	$2,462.60

EXPENDITURES.

All items	2,233.34
Surplus	$ 229.26

Note—The unpaid items are in the main not overdue,

The matter published is summarized as follows:

Printed Matter—	Pages.
Papers and Discussions	585
Abstracts	127
Proceedings	41
Library Notes	8
Advertisements	162
Title pages	6
Total	933
Illustrations—	
Full-page plates	42
Small plates	106
Full-page cuts	45
Small cuts	36
Inserts	9

The committee desires especially to acknowledge the material and cheerful assistance given by Mr. Nelson L. Litten, Secretary of the Society.

J. J. REYNOLDS,
THOS. T. JOHNSTON,
W. T. KEATING,
Committee.

REPORT OF THE CHAIRMAN LIBRARY COMMITTEE.

CHICAGO, Ill., January 3, 1898.

To the Western Society of Engineers:

GENTLEMEN—I have the honor to submit herewith, on behalf of your Library

Committee, a report on the condition and care of the library during the past year.

It is hardly necessary to state that a reference library such as ours can never be as useful to the members as it should without a special librarian, who is always at hand, who is well acquainted with the contents of the library and with the location of each of its volumes. A committee, consisting of members each of whom has his own personal duties to attend to, which cannot be neglected, is but a poor substitute.

Without tiring you with useless details, we will present an outline of what has been accomplished during the year.

CONTENTS OF THE LIBRARY.

At the close of the year 1896 there were 2,325 volumes on the shelves and in the book cases, exclusive of pamphlets, exchanges, etc. At the close of the year just ended the accession book showed an increase of 342 volumes, or a total of 2,667, by the following additions:

By donations	225 volumes.
By purchase	28 volumes.
By exchanges for duplicates	9 volumes.
By binding of previously unbound volumes	80 volumes.
Total	342 volumes.

In addition to these, orders have been placed for the purchase of about eighty new works, at an approximate cost of, in the aggregate, $180, among which may be mentioned the following important publications, with their list prices attached:

J. B. Johnson's "Materials of Construction"	$ 6 00
Thompson's "Dynamo Electric Machinery"	5 50
Releaux' "Constructor"	7 50
Merriman & Jacoby's "Roofs and Bridges"	7 50
Johnson, Bryan & Turner "Frame Structures"	10 00
J. P. Church's "Mechanics of Engineering"	6 00
Meyer's "Locomotive Construction"	10 00

Arrangements have been made whereby it is expected to secure an average discount of 25 per cent on the above purchases, and this effort, causing some delay, is partly the reason why these works have not already been received.

Arrangements have also been made for the binding of 50 volumes of the "Transactions of the Institution of Civil Engineers," London, at a cost of $53.10.

Among the new books purchased during the year were 11 volumes of the "Transactions of the American Society of Mechanical Engineers,"* at a price even far below the regular price to that society's own members. These numbers had been missing from the series in our collection, which had thus been made complete.

FINANCIAL.

In last year's annual report was an estimate amounting to $520, which was submitted as representing the needs of the library for the year 1897. At the beginning of that year a budget based on expected resources was prepared, by three committees jointly, to cover probable expenses for the society during the year. This budget was approved by the Board of Direction and contained a provision limiting the expenses for the library to $400. Some time later, to guard against threatening shortage in the society's treasury, this sum was reduced to $200; but, a more favorable financial outlook being apparent toward the close of the year, the $200 was reappropriated by the board and placed at the disposal of the Library Committee, thus making the total amount to be accounted for $507.98 when including an old, yet unexpended donation of $107.98 made for the "special purchase of new books."

* Second and third vols. The first previously on hand.

On the strength of the increase in its resources, the committee arranged for the binding and purchase of additional volumes, as referred to above.

The committee will not unduly lengthen this report with detailed expenses, accounted for by the secretary, but will only give the principal items in bulk, as follows:

Furnishing the store-room and transfer of matter thither		$ 44 87
Purchase of new books, etc		112 11
Binding of books		74 00
Miscellaneous expenses		14 73
Outstanding liabilities:		
New books ordered	$180 00	
Binding contracted for	45 00—	225 00
Unexpended balance		37 27
Total		$507 98

RECAPITLUATION.

Amount available for the expenses of the year	$507 98
Expenditures (including outstanding liabilities)	470 71
Balance available	$ 37 27

WHAT HAS BEEN DONE.

Among the first acts of the committee was the securing, free of charge, of the use of a store-room in the attic above the society's quarters, for the disposal of various bundles with periodicals and other matter, which had occupied much needed space in the rooms and disfigured these to a distressing degree. This was done in accordance with recommendations in last year's report. The store-room was furnished with shelving and the transfer made.

At the request of the committee, a fourth member, Mr. B. B. Carter, was added to it in July.

In the month of April the committee received an invitation from the John Crerar Library, through its librarian, Mr. C. W. Andrews, to co-operate with that institution. and was requested to furnish for that purpose a complete list of books and periodicals on hand, before the close of that month. The committee, finding it impossible to accomplish this in that space of time, took no action. It was, however, found later, in September, that arrangements could yet be made; the committee took the matter up, and with the aid of our secretary, prepared and furnished the desired information.

In brief, the plan of co-operation is about as follows:

The plan embraces some seventeen or eighteen libraries of this city, besides our own. Each of these is to be ultimately furnished with a catalogue of all the publications accessible in them, so that when application is made at any one of the libraries for a certain publication not found therein, information may be had as to the library in which it may be seen.

Valuable as this arrangement undoubtedly might be to many, it appears to have one serious drawback, viz.: That of making our library, without its special librarian, open to the general public. As, however, those who are likely to be referred to our library would, in all probability, be exclusively men of our own or kindred professions, the number would perhaps not be greater than could be accommodated, and the objection not so great as at first imagined.

The John Crerar Library has contemplated the purchase of a large number of engineering works—a considerable sum of money being at the library's disposal for that purpose—and, the librarian having expressed a desire for the aid of our society in the selection of the most desirable works in this line, a special committee, consisting of forty-nine members, was appointed by the president, in compliance with resolutions offered by Mr. J. W. Alvord, and passed at the meeting of October 20. With the traditional promptness of committees of this society, several members thereof have already indicated their willingness to act in the matter some time or other.

It will, however, remain for the successors of the retiring Library Committee to carry out the purposes of the resolutions referred to.

Some embarrassment had been caused by the accumulation of a large number of exchanges, etc., many of which it would not be practicable to bind, considering the great cost and limited means available, but which are, nevertheless, too valuable to waste. To overcome this difficulty, it was proposed—in resolutions offered at a society meeting on October 6—to offer to the Crerar Library the selection and acceptance of all such volumes that were not to be bound for our own use, provided, that those so accepted should be bound by the Crerar Library and kept accessible to our members. The resolutions were referred to the Board of Direction with power to act. The board approved the proposition, added to the above mentioned volumes any of the duplicates on hand which might be chosen, and directed your Library Committee to act accordingly. This has been done; the terms have been accepted by the Crerar Library, and the selection is expected to be made in the near future.

USE MADE OF THE LIBRARY.

In compliance with a suggestion in last year's report, a book was purchased and placed in the library, for the purpose of receiving the autographs of those who should call to gather knowledge and wisdom from the pages of its volumes: but, though the callers have been many, the modesty, so characteristic of professional men, appears to have prevailed and deterred them from affixing their signatures and testifying to their presence, as is indicated by the practically empty pages of that book. Thus no statement can be made that would show to what extent the library has been used.

In closing this report, the committee desires to say that its members have not been selfish or inconsiderate enough to so completely finish all work required in the library as to rob their successors of the much coveted privileges of making themselves useful to the society during the ensuing year. Should any uneasiness exist on this account, let us console the troubled ones with the positive assurance that there yet remains work to be done. There is, for example, the re-arrangement of volumes in book-cases and on shelves, so that all periodical publications, all volumes forming regular sets, are placed together, and likewise, as far as practicable (considering difference in sizes of the volumes), works belonging to the same "class," should at least be in the same cases. This should have been done when the card-index was made, but unfortunately, it was not.

The Committee also desires to make the following suggestion to its successors, viz.: The supplying of cards or blanks on which a member, in search of a certain book, not found in the library, may write its name, publisher, date of issue, etc., and deposit with the Secretary. This is done in some other libraries, and such cards would furnish valuable suggestions for the committee, when ready to purchase new books.

The duties of the Library Committee are such that frequent attention is desirable, making it inconvenient to await action by the committee as a whole. It has therefore been thought advantageous to subdivide, as far as practicable, the duties between the different members, each attending to his part when most convenient, and as agreed upon at occasional committee meetings, at which times reports and recommendations may be made by the members and further general plans agreed upon. Attempt was made to introduce this mode of working during the last year, but was decided upon so late that no special results can be reported at this time. It is believed, however, that a further trial would prove convenient and beneficial.

Respectfully submitted,

G. A. M. LILJENCRANTZ, Chairman.

FINAL REPORT OF 1897 ENTERTAINMENT COMMITTEE.

To the Western Society of Engineers:

MR. PRESIDENT AND GENTLEMEN: The society's organization of last year is a thing of the past, and our committee is out of date, but, as a report is over due from it, we now present the same and request that you will consider it our last act of office and relieve us of all further duty. Our last report was presented to the society October 20.

Our next society function was under the auspices of the Englewood & Chicago Electric Storage Battery Road, whose guests we were on the afternoon of October 23. Our place of rendezvous was South Park Avenue Station, on Sixty-third street, where the Alley L and the Storage Battery Road exchange traffic. At this point we were taken in charge by Mr. G. H. Condict, manager and receiver, who, assisted by Mr. E. R. Gilbert and Mr. B. J. Arnold, did the honors in a manner which showed that they were not only up in lightning railroading, but were also skilled in the amenities of life.

Two cars stood ready to receive our company, which numbered about fifty. When all were aboard, a crank on each car was slightly turned, and the unseen and, to some of us, mysterious power put the wheels into such rapid motion that we were soon at the power house miles away. Here we all disembarked and were inducted into as many of the mysteries of storage battery craft as our powers of comprehension would permit us to absorb. We have learned that Mr. G. H. Condict is responsible for the planning and equipment of this road, and the task set him was that it should be the exponent of the highest development of the art.

He associated with him Mr. J. H. Vail, of Philadelphia, and our fellow-member, Mr. B. J. Arnold, who is still the consulting engineer of the company. We are prepared to believe that a literal compliance with the requirements of the company has been achieved, for the power plant is a model of compact, convenient and economical working, and never have we visited any plant for the generation of power where such scrupulous cleanliness prevailed. We were shown the appliances for charging the batteries in the fullest detail; this work is done in the basement. The trays each contain 72 cells, constituting a battery; each cell contains nine plates—four positive and five negative. The negative plates are all of the "chloride" type, but part of the cars are equipped with the "Tudor" and part with the "Manchester" positives. The weight of each cell is 100 pounds, and the full tray weighs about 8,000 pounds. The cars are equipped with Walker motors each 50 horse-power. Batteries are charged at intervals of about two hours, or as long as it takes to make a round trip of 24 miles.

We were shown the boiler plant of three Heine water tube boilers with space for three more, the Greene fuel economizer and the Worthington cooling tower.

The engines and generators are arranged according to the Arnold system of power station construction. The generators are made by the Walker Company and the engines, two of which, 250 H. P. each, are now installed, are of the Williams design built by the Bullock Manufacturing Company of Chicago. A most satisfactory description of this plant in full detail is given in the Western Electrician of August 7, 1897, written by Mr. Geo. A. Damon. In the same issue is a paper by Mr. B. J. Arnold on the "Design and Construction of Electric Power Plants"

After an hour or so at the power plant we were carried further southwest to the end of the Morgan Park Branch and shown a very successful device for assisting the cars up a steep grade by means of a counterweight traveling in a conduit similar to that used for cable car work. The descending car draws the counterweighted truck in the conduit up the hill, the traction cable is thrown off ready to catch on to the next west bound car; as soon as it is hooked on the counterweight truck, which is held in position at the top of its incline, it is released and at once acts as an auxiliary to the motor of the ascending car and carries it up the grade.

From Morgan Park we were speedily returned to our starting point, where we left the storage battery cars with the feeling that we had had a most interesting and instructive afternoon. The practical working of the storage battery is a pronounced success, and its fate now depends upon its success as a dividend earner. When it establishes its claim to consideration in the eyes of the prudent investor of capital its future is assured, for its advantages over the cable system, the trolley or the electric conduit are so patent that there is no need to enumerate them.

At the time of our visit some of the batteries in use had made 8,000 miles and there was no marked deterioration in the battery plates. We have had

the privilege of seeing the proof sheets of a report prepared by Mr. George A. Damon upon the efficiency of this plant, giving the results of a series of tests made by him to determine its economy and ascertain what, if anything, can be done to increase that efficiency. At the time his tests were made the batteries in service had made records of from 8,000 to 14,000 miles. This report, which is full of interest, will appear in the Western Electrician for February 5; also in the Street Railway Review and in the Engineering News.

The next venture on the part of your committee was a lecture in Central Music Hall on the Sanitary District of Chicago and its work, by the chairman. This was undertaken with the most liberal expression of approval by the society at one of its meetings and by individual members outside of the meeting; it was delivered November 30; was attended by a corporal's guard of the faithful from the society and a forlorn hope of the general public, was a flat failure and did not pay expenses.

The last function for which we were responsible was the annual meeting at the Technical club. The speaker of the evening was the Hon. Orrin N. Carter, judge of the County court of Cook county. His words were as music to our ears, touching the chords of humor and stirring our pride in and love for our chosen profession with the finger of a master.

The messages of the retiring and of the incoming presidents, each full of interest for the society, and the reports of committees, were interspersed with impromptu talks from members and guests, all in happy vein. Good fellowship prevailed, and the occasion goes into our history as one of pleasing memory upon which we may congratulate the Society, and with the tender of our resignations we give expression to the hope that each new year may find the spirit of camaraderie strong and that its influence may be felt in ever widening circles.

We wish to give our successors in office a pointer, which, if followed, we feel sure will yield an evening of great enjoyment to our membership. Mr. Wm. J. Karner has a fine collection of slides illustrating Mexican scenery, public works and scenes from the daily life of the people, and he is able to please the ear with a discourse as vivid as his pictures. Need more be said?

ISHAM RANDOLPH, Chairman.
W. H. FINLEY.
G. M. WISNER.
A. C. SCHRADER.

ADDRESS OF THE RETIRING PRESIDENT, THOS. T. JOHNSTON.

Mr. Randolph: Gentlemen, we will now come to the point where one who has worn the armor, and worn it with honor to himself and credit to the Society, is about to put it off. You will now hear from our retiring president, Mr. T. T. Johnston. (Applause.)

Mr. Johnston: Mr. Toastmaster, and Gentlemen of the Western Society of Engineers: The time has come after three years service on the Board of Direction of the Western Society of Engineers, and last year as President, to lay aside the purples of office and invest others with them. Before doing this, however, I wish to congratulate the Society upon the Board of Direction which they have elected this evening, and their new and able President, who, I am sure, will lead the Society to greater prosperity during the coming year than it has had in any of its past years.

In the several years in which I have served in the Board, some events have happened which have been more or less useful to the Society, and have led somewhat, I think, to its improved condition.

In 1895 a sort of a revolution set in, in which, I believe, the chief conspirator was Mr. Charles E. Billin, who sits at the other corner of the room, and several of us assisted him as best we might in putting things in shape. One consequence was the development of the Journal of the Western Society of Engineers, and another the framing of a new constitution. The committee appointed for the purpose, found, in 1895, that it was costing the Western Society of Engineers, besides the labor of its Secretary, something like $1,500 to publish a few scattered papers subsequent to the time of their reading. As I

was saying with regard to Mr. Billin, he had some previous experience in matters of this kind, I think, with the Engineers Club of Philadelphia, and proved himself the guiding star which should be followed. The question of publishihg the papers of the Society was canvassed, and then was created the Journal of the Western Society of Engineers after some few months, which fact, I think, quite a number of us will recollect.

Just as the papers of the Society had not been published with entire satisfaction, so some other things were alike unsatisfactory, and it occurred to those instrumental in the revolutions taking place, and contemporaneously with the publication of the new Journal, to develop a new Constitution. This was done, and it was adopted at the annual meeting two years ago today.

At about the same time one of our fellow-members, Mr. J. J. Reynolds, concieved the idea that our Society did not have enough members, and started out to find members, and, I think, we received fifty to sixty members a month for a period, so that our membership list increased very rapidly; increasing from that time, I think, about 300 members three years ago today, to 411 at the beginning of the past year, and 423 today. This statement of membership I bebelieve to be bona fide and correct. With the activity connected with the development of the Journal, creation of the new Constitution and the increase of membership, came along the introduction of extended excursions, and in 1895 there was a notable excursion along the work of the Drainage Canal; there was also a very pleasant excursion upon Lake Michigan, and that was so successful that some difficulty was experienced in expending all the receipts of the event. In 1896 two extended excursions were made, which appeared to be not only very pleasant affairs, but were very important factors in getting our members acquainted one with the other, causing them to realize it was a good thing to belong to a Society of Engineers. The first one of these excursions, as you will remember, was to Louisville, Ky., and a good many of us will remember that a long time. (Laughter.) The next excursion, a month or so later, carried us to Rock Island, where we saw Mr. Modjeski's bridge, and, I am sure, our visit was very much enjoyed.

Another important development in these three years, and one that will stand our Society in good stead in the future, if it is carried on in the future as it has been in the past, has been in the matter of finances. Four years ago the Board of Direction of the Society had a pretty rugged road to travel in the matter of finance. At the end of 1895, under Mr. Horton's able direction, the Society showed some surplus; the following year Mr. Wallace had also reached a similar result, and we came pretty near showing $1,000 ahead; and today I believe, if all bills were paid, our finances would show us to have something like $1,500 ahead; if these figures can be continued for a few more years, prosperity will come without doubt. (Applause.)

So much for what might be called these important events which have followed one another during the last several years. There is one thing I would like to mention before leaving that general subject with regard to the cost of the Journal. In the estimates that have been made of the cost of the Journal to the Society, sight should not be lost of what it cost us before we had our own journal; not only what we paid out, but what we contributed in the way of labor by our Secretary, and by our members, reading proof and things of that kind. There is another thing which should not be lost sight of in counting the cost of the journal, and it is a matter of great importance to the welfare of our Society in this western country, the important list of exchanges which we receive of, I think, about 175 journals scattered over not only the United States, but the civilized world. In the library of the Western Society of Engineers can be found about all the good current engineering literature there is in the world; that I do not know how you can estimate in money value. (Applause).

Now passing to another theme, it has been said it is part of the duties of a retiring President to review engineering, and to ascertain its progress during the year previous to his retirement. There has not been a great deal of engineering progress or prosperity during the last year, and perhaps it would be easy to say all that can be said on that subject. There are one or two lines in which there has been some progress made, and concerning which, perhaps, a

few words of interest may be stated, and that is with regard to water ways. Chicago is becoming the centre of the universe, so far as water ways are concerned; we might mention the first one we ever had, the Sanitary District Canal. The progress upon that work during the past year has been very considerable although perhaps not very noticeable. The trustees of the Sanitary District I happen to know have labored hard, held meetings daily during a good part of the time, getting money matters into shape for further construction work; during the earlier part of the year they met a deficit, and were successful in convincing our Legislature that the deficiency was unavoidable, and got the Legislature to provide ways and means for a continuance of the work necessary for its completion, in the securing of the necessary right of way, and matters of that kind.

It might seem rather curious that it would be a matter of interest here to make any statement with regard to the Manchester Ship Canal. It has been regarded generally as a failure, but it is very far from being a failure. That the Manchester Ship Canal has been a failure is founded upon the information that has grown out of the fact that it has not paid satisfactory dividends to the particular people who invested their money in it. If the proper people, that is, the nation, had invested the money to build the Manchester Ship Canal, it would be said today to be paying them very large dividends. I get this information from one of our fellow-members, Mr. Metcalf, who is building a great grain elevator at Manchester, England, the people of which city came all the way to Chicago and into the ranks of the Western Society of Engineers to find a man to build them a grain elevator. It may be well to consider here why they are building a large grain elevator at Manchester. Mr. Metcalf has been in Manchester during the past fall, and returned for the Christmas holidays some two weeks since, and from him I have the fact which I am about to state; he has been there talking with their business men, met their engineers, is necessarily quite familiar with what has transpired in Manchester, and he says: "That the increase in value of property in Manchester at the present time, on account of the existence of the Manchester Ship Canal, far exceeds the cost of that Canal." (Applause). Looking at it from that point of view, we cannot call the Manchester Ship Canal a failure. Much more could be said in that line though, but this is enough to be suggestive at any rate.

The next deep water way or great canal which I might mention as a deep water way project, is from the great lakes to the Atlantic Ocean, involving as a matter of fact a comparative short mileage of canal. There are two events in the history of that project which are of interest to the Society at this time. One of them is a report recently made by a deep water ways commission, of which our fellow-member, L. E. Cooley, was a member, and who, as a matter of fact, wrote the report in question, and those who have read it I think will be found agreeing that he succeeded in doing a great deal. It is due to Mr. Cooley to state that his work upon this project has extended back to a period beyond a year previous to the publication of his report; that as a matter of fact he promoted the Legislation which created the commission upon which he served. He attended the great convention at Cleveland in 1895, and commanded the attention of the people of the far west and the far east, brought them together, and with the result that Congress was called upon to create a commission to consider the project in hand.

Following upon that the National Government has again come into the ranks of the Society of the Western Engineers to look after its interest in this deep water way, and has selected our new President as the man. (Applause). And I am quite sure that through the efforts of Mr. Noble and his associates they will add a great deal of information to the possibilities of the subject which they are considering.

And here again I would like to say one word with regard to the development of deep water ways from the great lakes to the ocean. There has been some criticism of the project, a kind of a scare, as possibly not of a nature to pay direct dividends; that does not, to my mind at least, convey the idea that the project will be by any means a failure. I dare say that every shipbuilder who attended the convention at Cleveland two years ago will help to develop

this project, and that the increase in shipbuilding in Lake Erie alone will more than justify the cost of any canal that can be built from the lakes to the ocean. (Applause.)

Next the Nicaragua Canal. And why should we here tonight be interested in the Nicaragua Canal? Because one of our honorod members has been taken from this Society last week and sent to Nicaragua to see what he could make out of it himself; he has built one canal, if any man ever built a canal, he has started another one, if any man ever started one, and failed with neither, and we might anticipate some results from his visit to Nicaragua. (Applause.)

It is worth while perhaps to go into a little detail in reference to this trip to Nicaragua. I have a letter written by Mr. Cooley the day before he sailed, in which he gives the personnel of the party going with him. I might state beforehand that this party is made up of a number of well-known contractors, two or three engineers and some people who expect to make a proposition to build the Nicaragua canal for so much money with the expectation of being able to raise money and get people to invest it in an enterprise. These gentlemen, as we might judge from their character, are very well assured they can do so or they would not undertake such a venture without the prospects being quite good at least. A number of these gentlemen have had experience in building our Drainage Canal, and it might be said they would know something of building canals from that fact. Mason, Hoge & Co., who built six or seven miles, six whole miles and part of another, are represented by H. P. Mason, head of the concern, and by Mr. H. B. Hauger, one of the best assistants that Mr. Mason had in his corps in working upon the Drainage Canal; from the Drainage Canal we have also Mr. J. M. Jackson, from the firm of E. D. Smith & Co., who, I think, is known to most of us here present; and it was said at the time of this writing that Mr. Smith himself, head of the concern of E. B. Smith & Co., formed one of the party. Either one of these concerns would be able to undertake the whole enterprise involved if it were awarded to them. One of our fellow members, Mr. Fred. Davis, is a member of that party and is expected to make some good judgment of what can be done on the work that is involved in that enterprise. There is also with the party Mr. Winston, of Minneapolis, and Mr. Stevens, representing McArthur Brothers, who have done some work upon the Drainage Canal; Mr. Arthur McMullen, and Mr. Frank Washburne, of New York; Mr. Dennis, of Rhineheart, Gooch & Co.; Mr. Little, of McMullen & Co., and Mr. Hooter, of Washburne & Washburne; L. E. Cooley, Mr. Cragin, J. E. Maloney, and Mr. L. L. Wheeler, geologist, form the party. They are all enterprising men and will surely find out as to what can be done, and we may expect that their return will be fraught with results that will be of great interest to all of us.

So much for the subject of water ways, I think it is sufficient ground for me to cover this evening. I wish, before closing, to thank all the members of the Society for the very courteous and helpful spirit which they have accorded the administration of the Society during the last year, and I wish that they will continue io assist the administration that is to follow. (Applause.)

Mr. Randolph: Our newly elected President has left his plow in the furrow, and before he goes forth to put on his armor he has something to say. Mr. Noble will address the meeting. (Applause.)

ADDRESS OF THE PRESIDENT-ELECT, ALFRED NOBLE.

I thank you, gentlemen, heartily and gratefully, for the high honor of election to the office of president of this society. I am well aware that this is not wholly, or even mainly, a personal compliment; but it indicates a contentment with the general policy of the administration of the society's affairs during the last few years. In this policy I had the good fortune to concur from the first, and have been identified with it, through your favor, for the last two years.

It has been customary for the incoming president to offer on occasions like this suggestions as to the policy thought most judicious for the society to adopt. This is not by any means laying down the course to be pursued, for he is only one member of the Board of Direction, which consists of seven, and the board is merely the servant of the society and will obey its dictates; so that between the preference of the president and actual performance there is a potential of

two vetoes—a power which should and will be exercised in the future, as in the past, with the utmost freedom and firmness, for this is the visible proof of a healthy interest and essential to a healthy growth.

I will follow precedent to some extent, and offer a few suggestions which seem to me in the direction of the good of the society. Before doing this, however, it may be well to consider for a moment what manner of society this is.

It was well pointed out by our retiring president in his inaugural address that the sphere of this society includes all branches of engineering. It is not a society of civil engineers or of mechanical engineers or of electrical engineers or of engineers in any single specialty, but it takes in all. The work of an engineer in any of these special lines is in almost every case related to the work of others, and the best results can only be reached by a mutual consideration of all the conditions of any given problem. Each must have an appreciation of all the requirements and adapt the solution of his own to the best general result. The union of engineers of all lines into one society promotes this general knowledge and broadens all.

Among the so-called local engineering societies of the United States, we were, at the beginning of 1897, the third in point of numbers, the Boston Society of Civil Engineers, with 431 members, and the Engineers' Club of Philadelphia, with 413, exceeding our 411. The Engineers' Society of Western Pennsylvania, with a membership of 401, followed closely. In respect to revenue, we ranked second, or third if we eliminate receipts on account of the Journal, and we now rank first if we include them.

Of the three societies mentioned, two publish their own transactions and one, the largest one, publishes its transactions in the Journal of the association. The Philadelphia Society publishes four numbers per year; the Society of Western Pennsylvania publishes ten thin numbers; both are excellent, but our Journal does not suffer, either in respect to quality or quantity of matter, by comparison with either. The position of the society among the so-called local societies may, therefore, be summed up briefly; we are nearly the first in point of numbers, probably the first as to resources and, we fully believe, the first as regards the Journal. We may well be gratified with our position, and particularly with our advance in recent years. The ever recurring questions are, how may this advance best be promoted and how may the revenue of the society be expended most wisely. The suggestions to be offered here are few and mainly in continuance of that line of policy which has proved so satisfactory to the society.

The engineering profession is in this country notoriously lacking in "espri-de corps;" largely on account of this it has failed to conquer a satisfactory professional standing. It is through such organizations as ours that this pride in the profession must be developed; we must seek to draw in all worthy and capable engineers, and we must as carefully exclude the unworthy. The growth in membership has been small during the last year, and particularly so during the last few months. The excursions of the previous year had been followed promptly by numerous applications for membership; the great excursion of the year just passed, the most extended, the most instructive and perhaps the most enjoyed of any the society has undertaken, did not seem to create interest to the same end, and it is particularly desirable at this time that the members make special individual effort to bring into our membership the large number of engineers of high attainments and character in this city who are not allied to any engineer society.

By the recent revision of the organic law of the society a provision which formerly existed for the remission of dues after a membership of 20 years was annulled. It was absolutely necessary to cancel this provision in order to maintain the organization; to many of us, doubtless to most of us, this was repudiation, and nothing but that principle of self-preservation which is nature's first law could justify it. Nearly all the members recognized the conditions and approved the action as the only practicable course under the circumstances, but unfortunately we have lost on account of it some of our oldest and most valued members. It is important in the highest degree to retain in our membership these veterans of the profession, not only to strengthen the

society by their knowledge and counsel, but by their example to induce others to avail themselves of its benefit.

Although classed as a local society, we are much more than that. The word Western which appears in our corporate name embraces in this country a large part of its area and a larger part of its ambition and vigor. Of the territory designated as "The West," the larger portion is strongly allied by material interests with this city as its metropolis. These conditions point to a future for this society as a sectional one rather than a local one, and we ought to draw from this section a large increase of membership.

That we are beyond the grade of a local society is shown by the fact that more than one-fourth of our members are non-resident. So large a proportion should have, it seems to me, a larger voice in the management; in fact, the present Board of Direction is wholly resident. It is necessary, for the convenient transaction of business, that the board should be composed mainly of resident members, but in my opinion the constitution should be changed so that the non-resident membership would have a fair representation in the board. The interest of non-resident members would be further stimulated by some more suitable arrangement for participating in the nomination of officers. Every practicable means should be taken to impress them with the fact that they constitute a valued portion of our membership.

The means for maintaining interest in the society, in addition to that professional spirit which all should feel, are intended to meet both classes of members. For the resident members there are the library and the regular meetings for the reading and discussion of papers; to the non-residents the Journal is of special value. The attractiveness of the meetings depends upon the efforts of the members to provide papers; it was to have been expected, perhaps, that the unusual exertions in this direction called out by the inception of the Journal would be followed by a reaction, and for the last few months there has been an undesirable decrease of activity. Good papers are not only the life of a society, but the discussions are pretty certain to develop points of value to the writer himself. It is to be hoped that interest of this kind may be renewed and that during this season of quiet in construction matters a large number of good papers may be prepared.

It was necessary for several years to use the utmost economy in expenditures. The scope has been gradually increased, and during the last year, for the first time in many years, there have been funds in the treasury at all times to meet bills as they fell due without the necessity of restricting the work as laid out, and without asking anyone to anticipate payments coming due to the society. The margin has not been a large one; the minimum bank balance during the year was about $700.

There is much difference of opinion as to the accumulation of a fund in excess of that required for current expenses. The American Society of Civil Engineers, it is well known, accumulated a large fund, which has been of vital importance in the development of that society, and if we were aiming at a similar development it might be sound policy to pursue a like course. Not long ago, it will be remembered, some of our most progressive members advocated a development into a national or international organization, but this idea, under recent adverse business conditions, has been laid aside as an effervescence of the enthusiasm of the World's Fair year. For the near future, at any rate, we are to remain the Western Society of Engineers, and our development is likely to proceed on much the same lines as heretofore; a large fund is therefore necessary. It seems to me, however, that we should have a balance at hand which would carry the society through one or two years of adverse business. This moderate fund can be accummulated gradually if present conditions continue without greatly restricting other very desirable expenditures, such as the enlargement of the library and the improvement of the Journal. The library will always be a worthy object of improvement. The standard of engineering works should be found on its shelves, and it should be kept up to date in a more complete manner than has been possible heretofore.

The society is justly proud of its Journal. During the last year it has practically paid for itself. If the former arrangement with the association had

been in force during the last year the publication of our papers would have cost $1,400 or more—equal to more than one-third of the society's revenue. It is not in the least degree flattery, but merely simple truth, to say that this remarkable showing is due in great part to the ability, loyalty and zeal of the Publication Committee. It is important for the society to realize fully the tact and energy which have been exerted in behalf of the Journal for this reason, among others, that if these had been less marked a different financial result might have been reached. The Journal will probably fall some time into less capable hands, and in such a case the moderate fund I have advocated would be extremely useful. No fear need be entertained of such a misfortune while the Journal remains under its present control, and I am sure this audience and the entire society will join me in the hope that the committee will continue yet a little longer the arduous and zealous labors by which we have been so greatly benefited during the last two years.

But even under this skillful management the Journal cannot be successful without the hearty co-operation of the members. The revenue comes mainly from the advertising columns, and those of us who can should help to fill them. A larger share of the revenue ought to come from subscriptions, and by obtaining them the members can give to the committee welcome aid. It would require no great effort on the part of any single member to increase the resources of the Journal largely in this way if all would join. Subscriptions may be solicited with a clear conscience, for any engineer who takes the Journal receives full value for his money. Further, we may be sure that thecommittee will improve the Journal to the fullest extent that the resources placed in its hands will permit.

The foregoing suggestions pointing to a larger membership, better meetings, a larger library and an improved Journal embody nothing extreme and make no demands with which any of us cannot easily comply, and none which we ought not to make cheerfully for the profession of our choice. If carried out to even a moderate extent, the present rate of development of our society, gratifying as it is, will be more than maintained.

Mr. Randolph: Gentlemen, we are told "an honest man is the noblest work of God." God's noblest work is, I think, a just judge. We have in our midst one of that kind, who has consulted the men here on so many occasions that I think he has a fellow-feeling for our members, and I am sure if he did mete out justice to any of us it would be tempered with mercy. Gentlemen, let me introduce to you Judge Carter, of the County Court. (Applause.)

(Judge Orrin N. Carter: Mr. Chairman and Gentlemen: After that introduction I do not know what I am to say to put me on a right footing with you. I was brought here under false pretenses by my Brother Randolph. He told me this was a very informal gathering of engineers by themselves—no newspaper men and nothing put down, as in my court room, were everything is taken down by shorthand reporters. I also find them here, although I thought I might be able to talk to you to my heart's content, and there would be no difficulty about it. (Laughter.)

He said if any of you ever got before me he hoped I would treat you fairly. I have heard a great many wild schemes floating around lately, so it is possibly a good thing to get me to come down here to investigate your sanity—I try people for these afflictions [laughter]—and along that line to find out whether you are proper subjects or not for such an investigation. (Laughter.) But I ought to tell you very frankly the reasons why I came down. Mr. Randolph told me I could make an informal talk. He told me he did not want me to make a formal talk; he said they never had but one formal talk here, and after that formal talk the man who made it went wrong. (Laughter.) So I am sure not to make a formal talk, as I don't want to be afflicted that way. What I say to you will be shot at random. Possibly you have heard the story about the old man and his son who went to do some shooting. The son shot half a dozen times and didn't hit anything, and the old man asked for the gun to see what he could do. He took the gun, and after pointing it in all directions, shot, hit a squirrel and brought it down. He said, "I told you I would do it." "Yes," said the boy, "but you aimed all over the tree, and of course you ought

to hit something." (Laughter.) Now, I may follow the same plan in making this informal talk.

Another reason why I am here is that some day I might be stranded and may want to get some help, and you have railroad engineers here who would possibly furnish transportation. Perhaps Brother Noble would give me transportation over his new waterway, and I would be very glad to accept it.

But seriously, gentlemen, when I accepted an invitation I did not expect I would be called upon to make a set speech. I told Brother Randolph that I didn't have time to prepare one, and he said I was not expected to make any. I also said to him that I was a very busy man, and might not be able to get here at all. He said that that was all right; that if I could not come he could easily get a substitute. I suppose he was thinking of himself as a substitute. Perhaps you do not know it, but when Mr. Randolph once gets started he can make a great speech. I had some experience with him a few weeks ago at a meeting in this room, and I know what I am talking about. Of course, he will deny now his ability in this line, but if I had not openly charged him with it here he would be in the same condition on this subject that an old and well-known lawyer down in the central part of the state was when, on being charged with being one of the ablest lawyers in the state, he was asked by an acquaintance how he was going to prove it. He said: "You do not have to prove it; I will admit it." (Laughter.)

In urging me to come he said: "Of course, you could make a good speech, whether you have any time to prepare or not." He may be sadly disappointed in the results, the same as Senator Carpenter, of Wisconsin, was with a young man that he took into his office when he was a partner of Judge Ryan, formerly of the Supreme Bench of that state. The judge was a very celebrated lawyer, and a very eccentric one, too. He had some ways of his own, as all lawyers possibly have. When he was working in his office he did not want to be troubled or bothered. This young man was very willing and very anxious to help everybody in the office, but he displeased Judge Ryan very much by trying to assist him. A few days after he came into the office Senator Carpenter went from Madison to Beloit to try a suit, and he told this young man: "Don't you go near Judge Ryan, because he is on a big case and he wants to be let alone." Well, the first day the young man was very anxious to help the judge, but he remembered the admonition, and kept out of his room. The next day he was there, anxious to help, and he went into the judge's room. After he had been in three or four times, Judge Ryan said to the young man: "I have a very important matter for Senator Carpenter. Can you get ready for the train at once?" He said he thought he could. He ran for the train, got there just in time, and when he arrived at his destination in Beloit he rushed up to the court house to find Senator Carpenter, who was trying a case before a jury, and after a while he got his attention and gave him the sealed note. Before Carpenter could read it the young man turned around and ran for the train, to get back as quickly as he could. Carpenter opened the note, which read: "Dear Carpenter—Please keep this blankety-blank fool out of my office." (Laughter.)

Mr. Randolph said I knew something about engineers. I have had considerable dealings with them, had a little something to do with their work. I can remember way back in my boyhood days, building mud dams and having the mud dams built by other boys above me give way, and the floods washing their dams and mine to destruction; I can recall building a snow fort and helping to defend one of the bastions, and because of its poor construction or the lack of bravery of the defenders, it was captured in the first attack. My next experience was with country ditches, and I graduated from that into the work of the great Drainage Canal, where I was associated with Mr. Randolph and Mr. Johnston, and many of the boys in the room. I then absorbed quite a little engineering knowledge, and I know something of engineers and their work. I am not sure that our Supreme Court, in referring to expert witnesses, did not include engineering expert witnesses when it said: "You can get experts to swear on all sides of all questions."

I know from experience that these people can have two plans for the same project, and perhaps both of them perfect. I have for the members of the Western Society of Engineers and for men of your profession a great admira-

tion, and I believe in your work. Sometimes you are called dreamers, sometimes you are charged with building air castles, but when we look back over the history of the last one hundred years, aye, the last twenty-five years, and see the results that have come from these air castles, then you ought not to be ashamed with being charged with being dreamers. I believe it to be true that before any of these great works that we are all so proud of now were accomplished, they were dreamed in the mind of some man, the picture of the subject was there before it was carried out, indelibly photographed upon some man's mind before it was built; these great buildings we see about us, these wonderful canals, these marvelous railroad achievements were all born, dreamed if you will, in the brain of some engineer before they were put on paper, before they arose in air. I have read within the last few months what, to me, a layman, was marvelous, perhaps simple to you with your engineering experience; you may have read it, but it will bear repeating if you have. In 1893, in a little stream, a branch of the Ganges, way up in the Himalayan mountains, a landslide came down into that stream and formed a dam 900 feet in height, and 3,000 feet long, and you all know what happened. Immediately back of the dam a lake was formed. Below it were several villages filled with people, and the English officers and engineers knew because that dam was simply earth work, no masonry, no solidity, that unless something was done to prevent it, a great disaster worse than Johnstown might occur; and they figured out that in litttle less than a year the water would reach the top of the dam, break over and then the floods would pour down the valley. They figured that upon August 15, 1894, the water would begin to go over; they measured and figured the fall along the line of the valley; they put down mile posts as you might call them to tell the inhabitants the distance they must go up the hills before the water came in order to be safe, and at the foot of the valley they put up work to protect the canal; they built telegraph lines in order to notify the people when to go up the hills to avoid the flood. Instead of August 15, on August 25 the water began to trickle over the top of the dam and seventeen hours later that whole great volume of water, 16,650,000,000 feet, rushed down with railroad speed. Just below the dam the height of the water was 260 feet; 13 miles lower down it was 160 feet in height; 72 miles below the dam it was 42 feet in height, and 150 miles down the valley it was 11 feet in height. Its velocity during the entire 150 miles averaged 18 miles an hour. During the first 12 miles it is estimated that it traveled at the rate of 27 miles an hour. Huge rocks in its pathway were ground to dust. All buildings and structures were swept away by this immense flood, and yet the only loss of life in the entire valley was one man and his family, a religious fakir, and he was lost because he refused to believe that Englishmen could foresee that the dam would break and the flood would come. Twice he and his family were carried to the hills forcibly, but he insisted on going back. I call that one of the miracles of the age. These miracles are happening today because we have the knowledge and enlightenment of such men as belong to this Western Society of Engineers. (Applause.)

Men with whom I am proud to associate and proud to be their guest; proud to be the guest of idealists and dreamers and wherever great works have been accomplished, in the first instance they have been conceived by these idealists and dreamers; and all great works, Mr. Chairman and gentlemen of this Society, of which I have known, have been accomplished by these dreamers and not by men who were thinking of their own material interests.

We are charged today with being materialists; that we wish to pile up wealth alone, and I think, perhaps, the great mass of people believe to be true the sentiment expressed by the newspaper paragrapher:

"What Midas touched would turn to gold,
What changes time doth bring;
Now touch a man with gold, behold!
He'll change to anything."

There is a common and strong feeling I might say in the community that this is true, but I want to say to you, experience has taught me that men who have accomplished these great works as engineers are not the men who have looked to material things like wealth as the chief things of life; they are not the

ones who have thought of making great material gains; they are the ones who have thought of these things as a means to an end. They have not been the ones who wished alone to pile up millions, and in my judgment no great work I do not know whether you will agree with me or not—but no great work will ever come from the mind of man when he is simply thinking of counting dollars from it. (Applause.)

I believe it was Emerson, that part mystic, part philosopher and part theologian, who wrote:

"Out of the heart of Nature rolled
The burden of the Bible old;
The hand that rounded Peter's dome,
And groined the aisles of Christian Rome,
Wrought in sad sincerity.
Himself from God he could not free,
He builded better than he knew;
The conscious stone to beauty grew.

"Earth proudly wears the Parthenon
As the best jewel in her zone;
And morning opes with haste her lids
To gaze upon the pyramids.
O'er England's Abbey bend's the sky,
As on its friend with kindred eye;
For out of Thought's interior sphere
These wonders rose in upper air,
And Nature gladly gave them place,
Adopted them unto her race;
And granted them an equal date
With Andes and with Ararat."

Now, I believe in these sentiments. I believe we ought to be idealists—that we must be idealists in order to succeed. When I think of the wonderful White City that existed a few years ago down on our lake front, which by some of you gentlemen and others of your profession was brought into existence in a day and disappeared in a night, then I am made to think of what Shakespeare wrote centuries ago when he said:

"Like the baseless fabric of this vision,
These cloud-capped towers, the gorgeous palaces,
The solemn temples, the great globe itself,
Yea, all which it inherit shall dissolve,
And, like this insubstantial pageant faded,
Leave not a rack behind. We are such stuff
As dreams are made of, and our little life
Is rounded with a sleep."

Gentlemen, if I were not a member of my own profession, had I the ability, I would choose your profession. I am not looking down upon my own profession, either; I have a high ideal of it. I believe in a high ideal for any profession, and I have as high an ideal of my own profession as that old English scholar when he said—

"Of law no less can be said than that her seat is the bosom of God; her voice the harmony of the world. All things in heaven and earth do her homage, the very least as feeling her care, and the greatest as not exempt from her power."

I have talked long enough for such an occasion as this; you will believe, if I talk longer, that I have a formal speech. In the name of those people who believe that the world is going forward, and not backward, in the name of all that is pure, ennobling and uplifting, in the name of those who feel and believe as I do that—

"Through the ages one increasing purpose runs,
And the thoughts of men are widened with the process of the suns,"

I say to you, Mr. Chairman, and to you, members of the Western Society of Engineers, in the future more strength to your arms, more power to your

brains, more energy to your plans, aye, more success to your dreams. (Applause.)

Mr. Randolph: Gentlemen, we have with us a guest tonight, one who holds the door wide to those who enter. Let me introduce Mr. C. W. Andrews, of the Crerar Library. (Applause.)

Mr. Andrews: Mr. President and gentlemen, I think I can make a better claim even than Judge Carter, as to false pretenses, because the toastmaster gave me no notice whatever that I was to talk even informally, but I think I ought to be able to say a few words to men whose training has been so close to my own at college and at the Massachusetts Institute of Technology. A man who is taught to observe physical facts must have a keen intellectual sympathy with the men who make use of those facts. You will not expect me, however, to speak from my former standpoint of chemist and scientific observer, but from that of the new work I have found here. This is the collection of the works of others, and not least the results and work of the past in the lines in which you are interested. That has been a pleasant duty as well as an important one, and we shall be grateful to you for the aid you can give us, and which you have promised to give us.

There is some doubt and some uncertainty as to the position of the libraries of the city, and perhaps some misunderstanding as to their future possibilities. It is the opinion, I think, of most librarians of the country that this city has as good a chance as any of becoming, outside of Washington, which has the great advantage of the government collections, the library center of the United States, and it is the wisdom of the boards of trustees of the various libraries of the city which has made this possible, in that they have decided that the city is a unit and not a composite of separate sections, and that the interests of the whole are to be considered paramount. That is why the John Crerar Library can hope to be of assistance to the members of this society.

You will find in that library works on social, physical, natural and applied science, including among the latter the works on engineering. Please note the use of the future tense. It is to be understood that our libraries are not complete, that they are only a fraction of what they will be in the comparatively near future, and consequently you must not expect much on visiting them now. Moreover, I might ask that you should have a little consideration for the librarians. We have to pretend to know everything while we are fully conscious we do not; we are apt to make mistakes; we put some books where the professor of physics might want them, and not where you will want them, but you will kindly remember that we shall put other books for your convenience in places to which he will object. We have, however, made accessible a full catalogue of the books; have provided a reference librarian, whose first duty is to answer questions, and in all ways shall do our best to enable you to make use of what we have.

You see that I have no prepared speech to make, and I will close by saying, besides the intellectual pleasure I have had in being here, besides the professional pleasure of coming to say something for the library which I represent, I have had the personal pleasure of meeting many friends, and I thank you for all three.

Mr. Randolph: Gentlemen, I venture to say there is not a man in this audience who has taken more sincere pleasure in our growth, and the prosperity of this society, who is more interested in its success today than our old friend, Mr. Morehouse. I know there is no man in the audience from whom you will be more glad to hear than from him. (Applause.)

Mr. Morehouse: Mr. Toastmaster and gentlemen, I am the first one to rise tonight, without in any way knowing that the management of the evening intended I should have anything to say, and I do not see why I should be called upon in this way to be offered up as a sacrifice to you on the say so of the toastmaster without any notice whatever. It is a difficult position to be placed in. I know very little about law, but I have read that when a man is going to be hanged they give him some notice beforehand, but with me this is the first intimation I had that I was to offer myself up for your amusement. (Laughter.)

I assure you, gentlemen, however, that it gives me much pleasure to stand here before such a representative gathering as this, a society with which I have

been connected since its organization, originally the Civil Engineers Club of the Northwest and afterwards the Western Society of Engineers. It is a source of gratification not only to myself, but to many of those who are here tonight to realize that it has so ably and so successfully overcome difficulties which surrounded it for so many years. Having said this, which it is not difficult to say, I am obliged to confess I am incapable of speaking further in such a way as to interest an audience of this character.

My education as a public speaker has been very much neglected, and surrounded by the galaxy of talent which is present, I realize my own inability to speak in a way which I would like to. I think, however, that this may be a warning to the younger members present by which they may profit so that as they go on in life they may fit themselves for any occasion where they may be called upon to speak or to do any particular thing. And on this occasion I might unbosom myself a little to you (it is all in the family) and confess that I am unequal to many things. There have been many times when I have not been able to rise to the occasion. For instance, not a great while ago I had been explaining to a young lady something about the bicycle, and having satisfied her curiosity and desire for information as to why the hind wheel revolved as it did, she said: " What makes the front wheel go around?" (Laughter.) And I said: "That is too much for me." (Laughter.) I was unable to explain that except by a very long dissertation. Now, had I been an accomplished mechanical engineer I would have been able to explain why the front wheel went around. (Laughter.) So you can understand how much I regretted at the time my incapacity in that direction.

And it happened not a great while ago that I was compelled to admit my incapacity in another direction. I was in the city of Indianapolis and was taking a ride on an electric car, and as we passed through the city the trolley wires were suspended from posts in the center of the road, there being a track upon each side, but as we passed out of the thickly settled part of the city and ran through a patch of woods the central posts disappeared, the wires being suspended from side posts, and I noticed a couple of ladies sitting near me who were discussing the scenery, the twilight, the line, etc., and I heard them say: "What holds this wire up here, there are no posts here," and one of them turned to me, and she said: "Do you know what holds these wires up, there are no posts here?" I said: "I am a stranger here (Laughter), I really can't explain." I did not smile as you do (Laughter), I said: "Perhaps it is the dynamo." (Laughter).

Now if I had been an accomplished electrical engineer, I might have told that lady what held those wires up, I have no doubt. I have another story I will relate before I sit down, because my incapacity is very great indeed. I was riding on the Alton Road not a great while ago, this side of Joliet, and as we passed by those immense mounds which Mr. Randolph and some of my other friends have been building up there for the last two or three years, I explained to a lady who was sitting next me whose curiosity was aroused by them, that the Sanitary District Canal was being excavated. "Yes, she had heard about it. That was the canal, was it? And what an awful thing it was going to be! When it is done it is going to poison all the people below here!" "Oh, yes," I said "I have heard something about that." "And it has already killed all the fish." "Killed the fish!" I said, "Excuse me, what fish?" "Why, I don't know exactly what fish. I think the fish in the Chicago river." (Laughter). Well, I did not laugh. I said: "Really that is very bad, I hadn't heard of that before. I did know the fish in the Chicago river were killed, but I didn't know the canal did it." (Laughter.) When I see Mr. Randolph—I happen to know Mr. Randolph, the engineer—I am going to ask him about it. "Well," she said, "I don't know, I heard it was so. I live in Toronto." (Laughter.) Tonight I find there are other people in Toronto who believe the Sanitary District Canal is going to work terrible injury in another direction, so I can understand why my friend, the lady, thought the fish were already killed by the Sanitary District Canal. (Laughter.)

I was going on to say if I had been a good hydraulic engineer, and a good sanitary engineer I should have been capable of telling her why the fish in the Chicago river were killed by the canal.

This is another illustration and is a further reason why people should be able to answer all sorts of questions, and be ready for any emergency that may arise, including public speaking.

Now there is one word I might add before I sit down, in relation to the society, in all seriousness. It seems to me that when we are amending our constitution the next time, we should add an amendment. As it is now we elect our best men as we can get to them, we cannot elect them all at once, but we intend in time to select them to the office of president. A president serves one year, he takes great interest in the affairs of the society, and when the year is ended he steps out from the position, the highest position

The toastmaster called upon Mr. Horton to make a few remarks, but the gentleman declined, and Captain Hunt was called for; some one remarked that the Captain had escaped.

Mr. Randolph: This reminds me of a story my father told me many years ago, which occurred at a prayer meeting. One John Copelin was called upon to pray. Brother Copelin led the prayer and everybody knelt down, and there was a dead silence, not a sound. At last one old gentleman arose up and said: "Well, brethren, if you are waiting for Billie Copelin to pray, you might as well get up." (Laughter.)

When I was a boy I was very fond of field sports, my dog and gun were to me a source of a great deal of enjoyment, but there was another kind of a hunt that I enjoyed, a still hunt. I always liked one, because of the cheerful hand, and, therefore, I will call upon Captain Hunt to address you. (Laughter and applause.)

Mr. Hunt: I do not know much about the hunt that Brother Randolph speaks about, but, coming from the South as he does, I should think he would take great pleasure in "still" hunts. (Laughter.) I want to assure you, gentlemen, how joyful these occasions always are to me, and particularly when this society listens to such reports of its conditions as those with which we have been favored tonight. We went through some troublesome times and the year which brought to this city part of its great reputation was the crucial year for this society. It was then, I think, the membership realized the unfortunate condition into which we had drifted and were willing to put aside personal feelings, and recognize the fact that, if we were to live, it must be on strictly business principles. Then the revolution, if it might be so called, of that year followed, and the loyal efforts of the membership have led to our present comfortable estate; and those who have labored so faithfully and so loyally to bring that about deserve our earnest gratitude and affection. Gentlemen, this organization is one of which we can always feel proud. It has become an organization to which it is an honor for any man to belong. It has been our fortune to give to the world, to give to our nation, at least, an exemplification of the fact that in our membership we have men capable of filling positions where the greatest executive engineering ability is required. It is quite remarkable that we should have had such experience, and I defy any national society, certainly in this country, to point to membership which has exceeded us in this; or to point to greater success of executive officers than has followed the engineering work of members of the Western Society of Engineers. (Applause.)

The gentleman who has just left us (Mr. Wallace), to whom I know we all extended the warmest welcome on having him back again as a fellow-citizen, this man who demonstrated it was possible to carry hundreds of thousands of people, yes, demonstrated it was possible on his one line of road to carry practically three-quarters of a million of people within ten hours, safely and with comfort, the man who expended millions of dollars for the organization which he represented without the slightest suspicion that all of those many thousands were spent other than right, is a member and was an officer of this society. We are proud of his honor, of his glory, of his achievements, as being one of ourselves. (Applause.)

This great Chicago Drainage Canal, which has been most properly alluded to so many times tonight, and which should always be spoken of by our members on such occasions as this, because from its inception, from the time to

which our guest so eloquently referred, down to its almost accomplishment, it has been in the hands of the honored members of this society.

When the government hesitated whether or not it was right to open a waterway connecting the waters of the eastern seas with those of the west it came to this society to find a man to give it an honest report, and we tonight have elected that man as our president for the ensuing year. (Applause.) And from his report, which, while it perhaps did not suit the politicians at Washington, the government of the United States recognized that he was properly the man to take up what, in my judgment, is a greater work, that is, report upon and carry forward that great scheme of connecting our great lakes by a ship waterway with the ocean.

I have yet to hear of any charges made against the engineering force of the Drainage Canal; of any charges of a political nature being made by the people; any claims that it is a private enterprise. I have not yet heard the slightest intimation, even by that press which can so easily cast slurs of which no subsequent retraction will wipe away the scars. I have yet to learn of the slightest reflection upon the honor and integrity of the engineering corps carrying forward that great and magnificent work. (Applause.) Why, gentlemen, do you know that I almost feel as though that ditch belonged to this society? (Laughter.) Whenever I have an opportunity to speak of it, I call it *our* canal. Why not? Our members, from its beginning, have participated in the glory of it.

Gentlemen, we are in the midst of a peculiar condition of affairs. Changes have come and a new force now controls the affairs of the world. We can find little in the past on which to base our judgment as to the outcome. I refer to the great aggregation of capital, this bringing together of great interests under one organization. To many minds it is a menace; in the judgment of many it means a loss of opportunity to the individual. Now, is that quite true? I do not believe it. While it may be true, the individual as the head of the enterprise, the individual as the leader of a smaller organization may be lost sight of, but in my judgment it will open up great opportunities, particularly to the engineering profession, such opportunities as the past has never given. What does it mean, these millions of dollars coming together and invested in enterprises, in the development of manufacturing, in great schemes? That money cannot be absolutely spent by the man who writes the cheques; who nominally controls those millions which are to be put into such enterprises. Of necessity they must be entrusted to men trained to the occasion. And in no walk of life will such men be found, more capable of handling these large interests, than in the engineering profession. Now, what does it mean? It means that the man who is entrusted with such authority, the man who has faithfully carried out the execution of such trusts, will be paid for his work; it means that the success of that work will bring glory, not to Morgan & Co., but to Horton, to Randolph, to Johnston. To all such men in our and other similar societies.

Therefore, gentlemen, I think any young engineer, instead of feeling that there will be no place for him, that he is to be confined to the draughting room, or to subordinate positions in the corps in which he serves, can take heart and believe it is quite possible that there is room above to which he may climb, if he has merit and develops it in the accomplishment of great results. Because never yet have such results been accomplished except by work, hard work on the part of the individual. Work makes heroes, and heroes ever have and ever will go forward and onward to glory. (Applause.)

On motion of Mr. Ralph Modjeski, duly seconded, the meeting adjourned.

REGULAR MEETING—2nd OF FEBRUARY, 1898.

A regular meeting (the 377) of the Society was held in its rooms, 1736-9 Monadnock Block, Chicago, Wednesday evening, 2nd of February, 1898. President Alfred Noble in the chair; 70 members and guests present.

The reading of the minutes of the previous meeting was omitted as the members already had them in printed form.

The secretary reported for the Board of Direction the receipt of applications for membership from David Sloan, F. B. Badt, Frederic Sargent, H. J. Westover, Oscar Sanne, Wm. Kramer, J. G. Giaver, J. W. Page, G. H. Hillebrand, David Macdonald; for junior, G. C. Geraty.

Mr. Isham Randolph, chairman of the 1897 entertainment committee, read the final report of the entertainment committee, the full text of which apappear in the February issue of the Journal.

It was moved and seconded that the report be received, accepted and placed on file. On motion, a hearty vote of thanks to the committee for their successful labors dur ng the past year was seconded and carried.

Mr. Reynolds movied that the chair appoint five members as Entertainment Committee for 1898. Carried. The Chair stated that he would announce the committee later.

There being no further business, the reading of the paper of the evening on "Some Engineering Features of the Nicaragua Canal," by Mr. A. Noble, was in order. The first vice-president, Mr. J. J. Reynolds, took the chair and Mr. Noble proceeded with the paper. At its conclusion Mr. Geo. S. Morison and others entered into discussion of the subject. After the subject was disposed of the Chair called upon Mr. Condron, chairman of committee on professional papers, for report on progress of the committee. Mr. Condron stated that a dozen or fifteen papers were promised for the first six months, and that the committee were very much pleased with their success.

SPECIAL MEETING, 16th OF FEBRUARY, 1898.

A regular meeting (the 378) of the Society was held in its rooms Wednesday evening, February 16, 1898, 1st Vice-President James J. Reynolds in the chair; 45 members and guests present.

The minutes of the previous meeting were read and approved.

The chair called upon Mr. T. L. Condron, chairman of committee on papers, for report.

Mr. Condron presented a program of papers for the coming six months, and stated copies of the program would be mailed to all members in a few days.

There being no further business, Mr. Victor Windett read his paper on "The South Works of the Illinois Steel Co.," illustrated with a large number of views of the works. At the finish of the paper Mr. C. E. Stafford, manager of the Open Hearth Plate Mill Dept., gave an interesting explanatory talk on the subject, and was followed by Mr. Davison, chief chemist, with much matter of interest, Messrs. Albert Reichmann, A. M. Feldman, T. L. Condron, J. C. Bley, V. Windett also added to the discussion. At the conclusion a vote of thanks was cordially tendered Messrs. Windett, Stafford and Davison.

The meeting adjourned.

NELSON L. LITTEN, Secretary.

LIBRARY NOTES.

The Library Committee wishes to express thanks for donations to the library. Back numbers of periodicals are desirable for exchange and aid in completing valuable volumes for our files.

Since the last issue of the Journal, we have received the following as gifts from the donors named:

U. S. Coast & Geòdetic Survey to June 1896.
O'Chanute.—L'Ouvrier Americain, by E. Levasseur.
Metpn. Sewerage Com. of Mass.—9th Annual report of the Board to Sept. 30, 1897.
F. King & Co., London.—The Automotor and Horseless Vehicle, Pocket Book of Automotive Formulæ, etc., 1898.
Institution Mechanical Engineers, London, Eng.—Vol. IV, November, 1896,
Proceedings, Vol. I, February, 1897.
Proceedings, Vol. II, April, 1897.
G. S. Morison.—Reports Board of Consulting Engineers, Dept. of Docks, New York City, 1897.
Mass. Inst., Technology.—Result of Test made in The Engineering Laboratories, Vol. IV, Description and Computation of a 24 hour Duty Test on the 20 Million Gallons Leavitt Pumping Engine at Chestnut Hill.
State Geologist, Iowa.—Iowa Geological Survey Reports Vol's. I to VII, 1893 to 1896, inclusive.
O. B. Green.—R. R. Comrs. Reports, 1890, 1896, 1897.
W. O. Seymour.—45th Annual Report (1897), R. R. Comrs. of Connecticut.
Harman, Jacob A.—12th Annual Report of the Illinois Society of Engineers and Surveyors. January, 1897.
U. S. Department of Interior.—Annual Report of the Commissioner of Patents for 1896.
Annales des Ponts et Chaussees.—1897. 3me Trimestre.
Ohio State Board of Health.—8th Annual Report. 1896.
Massachusetts Institute of Technology.—Result of Tests. Vol. V. Applied Mechanics.
Result of Tests. Vols. VI and VII. Applied Mechanics.
The Federated Canadian Mining Institute.—Journal of. 1897. Vol. II.
Iowa State Agricultural College.—Catalôgue. 1897-8.
Boston Transit Commission.—3d Annual Report year ending August 15, 1897.
U. S. Bureau of Foreign Commerce.—Consular Reports. January and February, 1897.
Nobe, Alfred.—Transactions of Institution of Civil Engineers. London. Vols. I and II. 1836-1838.

The following books received by purchase:

Materials of Construction	by J. B. Johnson	Modern Machinist	Usher
Electric Power Transmission	Bell	Steam Engine	Holmes
Electric Railways	Dawson	Freehand Lettering, Etc	Daniels
Electric Smelting	Borchers & McMillan	Mechanical Drawing, Etc	Anthony
Otto Cycle Gas Engine	W. Norris	Text Book on Machine Drawing	Anthony
Rational Heat Motor	Diessel	Essentials of Gearing	Anthony
Architects' Pocket Book	Kidder	Treatise on Belting	Cooper
Heating, Etc., of Buildings	Carpenter	Modern Steam Engines	Rose
Roofs and Bridges, Vol. II and III.	Merriman	Compound Locomotives	Woods
Modern Framed Structures	Johnson	Heat as a Mode of Motion	Tyndall
Experimental Engineering	Carpenter	Machine Drawing and Design	Low & Bevis
Mechanics of Engineering	Church	Complete Practical Machinist	Rose

American Foundry Practice .... West
Moulders Text Book .... West
Fire Protection, Etc. .... Woodbury
Higher Mathematics .... Merriman
Dynamometer, Etc.................... Flather
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XXIX.

THE EVOLUTION OF THE AMERICAN TYPE OF WATER WHEEL.

By W. W. Tyler.

Read March 2, 1898.

The peculiarity of American water wheels is that they receive water on the periphery and discharge it downward and toward the center while the foreign wheels receive the water on top and discharge it below, or at the center and discharge it outward.

Fig. 351 is a cut of the Victor Turbine, which is a good representative of the Americanturbine. Fig. 352 shows the New American turbine wheel mounted in a wooden flume. Nearly all wheels now built in America are mounted in this way in iron or wooden penstocks. The water is carried by a flume to the penstock in which the wheel rests. The wheel covers a hole cut in the floor. The water flows through the wheel from the penstock and thereby imparts motion to it. Below the wheel and penstock is a large channel through which the water escapes.

This type of wheel, which is peculiarly American, has been slowly evolved from very imperfect forms until it has become superior to all others. The history of the American turbine is an illustration of American ingenuity combined with that unfaltering faith which does not hesitate to spend hundreds of thousands of dollars in developing inventions.

In the year 1859 the committee of water-works of the city of Philadelphia instituted a series of competitive tests of water-wheels to enable them to select the best design for new pumping works which were about to be erected in Fairmount Park, on the Schuylkill River. The results of those tests were afterwards published in a pamphlet which gives the general condition and state of the art at that time. The Jonval, or French type, gave by far the best results. It is illustrated by Fig. 353. This wheel led those tests with a high record of 87.77 per cent efficiency. The wheel

which showed the next best record, and which afterwards received the contract and was adopted by the city, was of essentially the same description.

Seven wheels of the class which takes water on the outside and is now universally adopted by American builders, were tried at the same tests. Their average efficiency was 12½ per cent less than those of the Jonval type, and in selecting water-wheels for the city the committee would not consider them because their efficiency was so low. This shows how completely in its infancy was the American type of water-wheel in 1859.

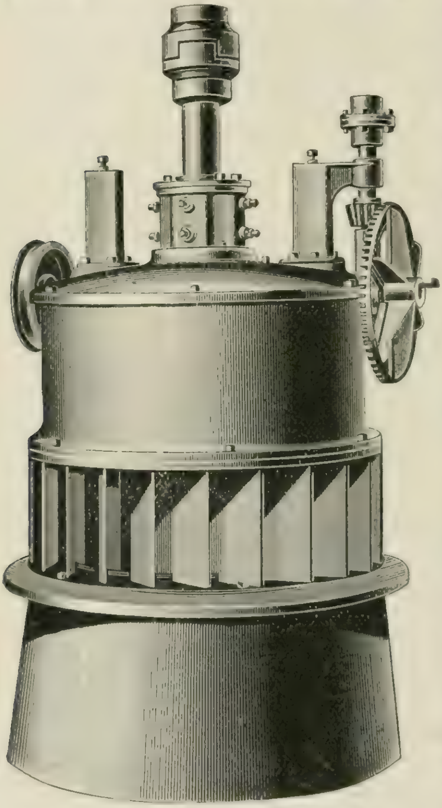

FIG. 351. VICTOR TURBINE.

In 1876, seventeen years later, another competitive test of water-wheels was carried on in Philadelphia at Fairmount Park. This test was under the auspices of the Centennial Exposition. Sixteen water-wheels were tried. Fifteen were of the American type. The only Jonval wheel, or wheel of foreign type, was entered by the same manufacturers who secured the order which depended on the tests of 1859. Their wheel was designed by the same French engineer who had been trained in the best French schools, where he had studied the best French models. Its chutes and buckets were set in finished grooves, cut with perfect accuracy. They were made of rolled brass, so as to allow the water the smoothest and best course.

The American wheel which led the test in 1876 was a Risdon wheel, a plain iron casting. It is illustrated in Figs. 354 and 355. It was from five to ten per cent. better at full gate and gave 33 per cent. more power out of the water at part gate, so much had the American type of wheel been developed at that time. By comparing it with the Watson-Stevenson wheel, Fig. 353, which gave the best records in the tests of 1859, the difference between the French Jonval type and the American type will be easily perceived.

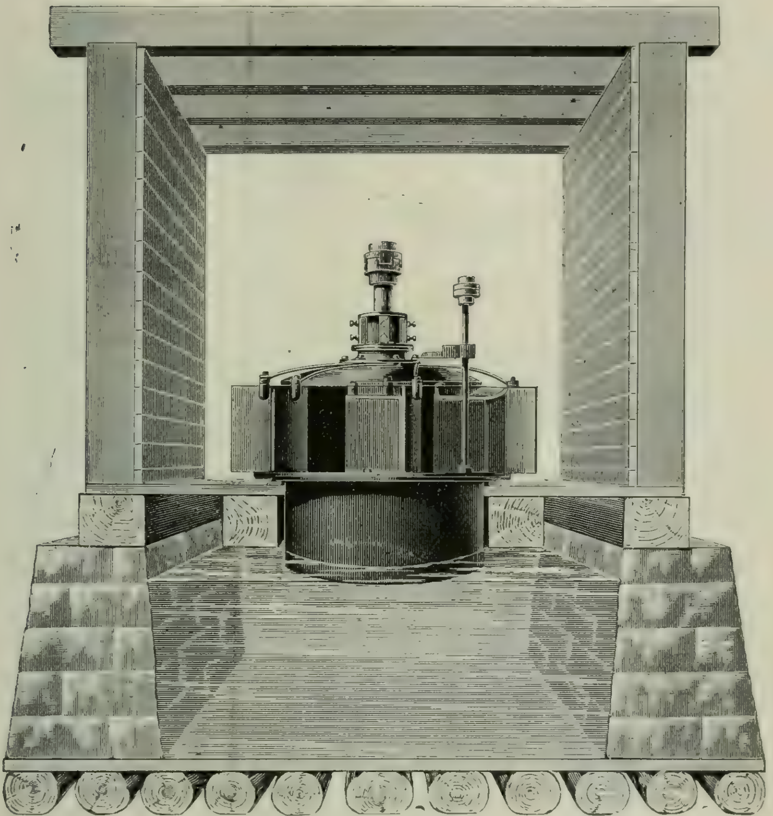

FIG. 352. NEW AMERICAN TURBINE MOUNTED IN PENSTOCK.

From 1859 to 1876 a corresponding change had been going on among our large New England factories. There, in 1859, the French Fourneyron turbine, Fig. 356, had crowded out the old pitch-back breast wheels and had obtained high records.

At the Atlantic Cotton Mills, at Lawrence, Mass., Mr. U. A. Boyden (designer of the Boyden Fourneyron), of Boston, claimed an efficiency of 94 per cent. Since the amount due to him for his designs depended on their efficiency, this claim was carried into the state courts, which, after referring the matter to a board of arbitration composed of prominent engineers, granted to him a claim of 92 per cent., and he received his pay for wheels of that efficiency. At that time few experiments had been made upon the flow of water over large weirs, and it was afterwards found that Mr. Boyden's weir formula was erroneous, and made the quantity of water flowing over the weir three per cent. too small. But even a record of 89 per cent. is very high.

After 1876 the American type of wheel almost completely controlled the New England trade. The Fourneyron wheel was expensive to build, it clogged easily, it was not efficient at the part gate, and it ran too slowly. Now to the origin and history of this great change. Until 1850 there was lacking a simple water-wheel which could be used on large streams where the water in the tail-race rises in every storm, and destroys the efficiency of a breast or overshot wheel. This was especially true of saw-mills. They were used only in winter and spring when the supply of water was ample and it was not necessary to economize it. At first the flutter-wheel was used, consisting only of a wheel with a set of square blades, against which a sheet of water impinged and gave force. They only gave an efficiency of about 30 per cent. but that was enough. The flutter-wheel would not run in back-water and every storm stopped the mill. This led to the adoption of the reaction wheel.

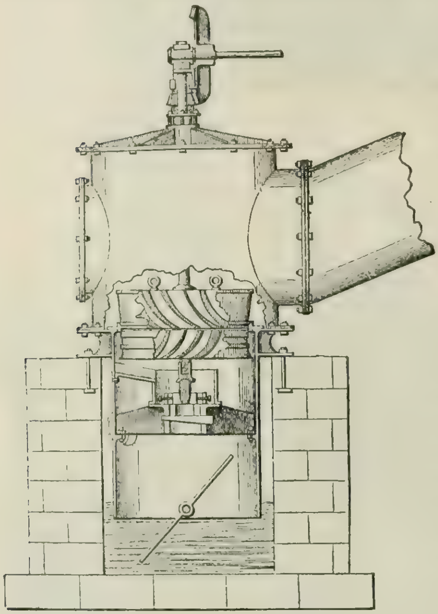

FIG. 353.—JONVAL TURBINE—WATSON-STEVENSON.

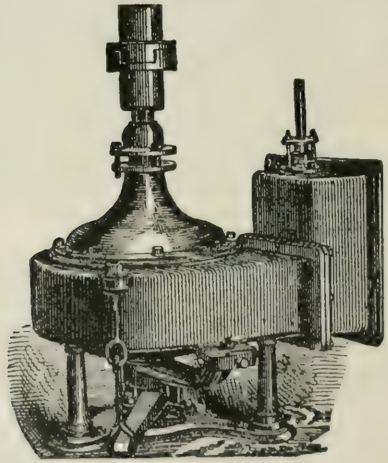

FIG. 354.—RISDON TURBINE.

View of wheel proper, or the part that revolves.

FIG. 355.—RISDON TURBINE.

In Fig. 357 is given a cut of the Andrews & Kalbach wheels

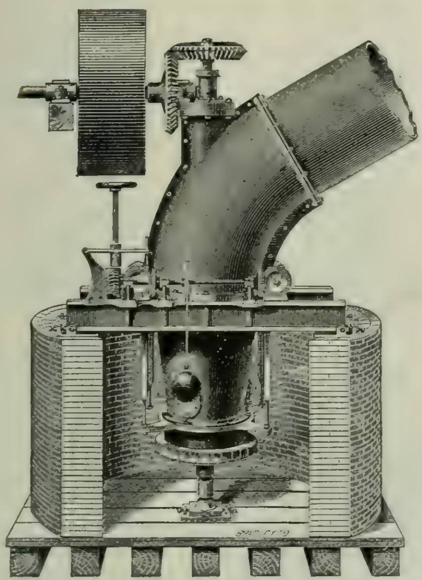

FIG. 356.—BOYDEN-FOURNEYRON TURBINE.

taken from the report of the committee on water-works of Philadelphia, already quoted. This wheel gave the best percentage of efficiency of any of the American types at that test. It is the American type only in embryo, but all the elements of the most improved type of water-wheel are there.

Fig. 358 shows one of the best of modern wheels from one of our leading manufacturers. A comparison of the two will show the improvements of forty years. Fig. 359 illustrates a single wheel mounted on an iron helix or scroll. The model, Fig. 357, has two such wheels placed on opposite ends of the same shaft. The water there is let into the flume between them in such a way that it can only escape through the water wheels.

Passing through the curved vanes of such a wheel, even if it had no stationary chutes or guides, would give the water a whirling

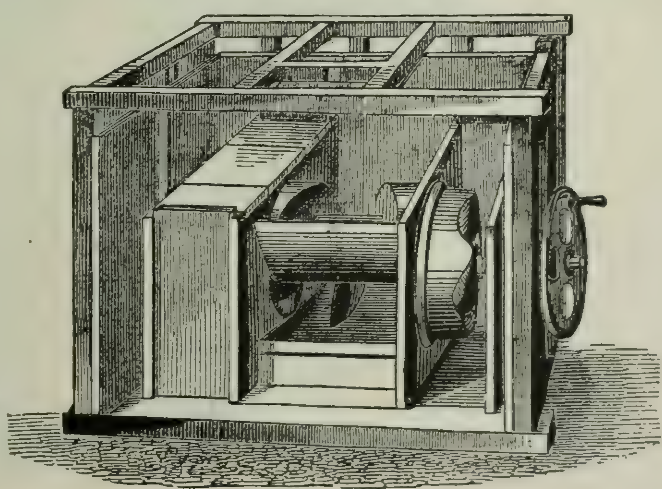

FIG. 357. MODEL OF ANDREWS & KALBACH WHEEL, MADE IN 185[illegible].

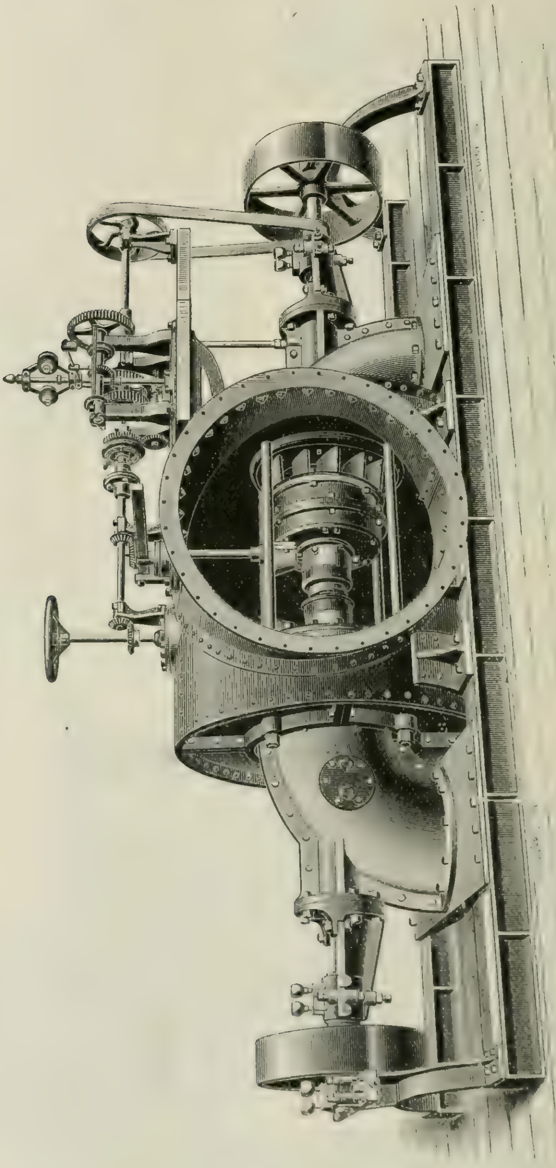

Fig. 358. Pair of Turbines on Horizontal Shaft.

motion. This throwing of the water in one direction would, by its reaction, force the wheel in an opposite direction, just as the shooting of a cannon throws the cannon in the opposite direction to that in which the ball flies. Each of these wheels was in principle a cannon throwing an infinite number of balls, and was moved itself by an infinite number of reactions. In the cut of the Andrews & Kalbach model (Fig. 357) the water is led into the wheels by chutes or scrolls, but in actual practice the chutes were rarely used. The writer never saw one of these wheels with chutes. The cut is taken from a model and not from a flume or large wheel. It has a fly wheel at one end of the shaft to show how the pitman or crank-shaft would be attached to it. There are also draft-tubes into which the wheel would discharge the water so that no fall would be lost after the water had been discharged by the wheel. But the writer never knew them to be used. The model was made for use in selling wheels, and shows how these principles could be developed, but in all ordinary trade the wheels were used without stationary guides or draft-tubes. They gave an efficiency of about 35 per cent, and had this great advantage that they would run in back-water.

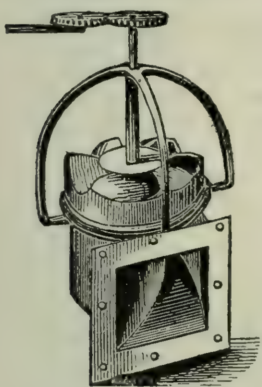

FIG. 359.—SINGLE ANDREWS & KALBACH WHEEL MOUNTED ON IRON SCROLL.

The efficiency was low, but it satisfied the owners. The writer has recently been testing wheels made by our best manufacturers and which are in the path of the Chicago Drainage canal. They have averaged less than 50 per cent efficiency. The writer once thought that a good efficiency could be obtained from wheels without guide curves, and designed one with the greatest care. Several turbines of his design had given 90 per cent in the old Holyoke testing flume and he hoped for a high rate of efficiency which would be found in a wheel adapted to a class of work which did not require great economy of water. This wheel when tried in a good testing flume, with Prony brake and weir, showed an efficiency of only 51 per cent. He then believed that the cause of his disappointment was the use of long vanes and water courses when the reaction wheels in common use had only used short ones. This led him to construct and test a new wheel with short vanes but that gave only 42 per cent in the same testing flume. He was then a partner in an old and well established business which had made and sold many of these wheels. So he asked the head of the firm whether the failure to obtain a good percentage was not unaccountable, considering the good satisfaction that class of wheels had given. The gentleman replied that,

although he had sold many of them, he did not believe them to be capable of an efficiency of above 40 per cent.

The water would run through a wheel of that description more than twice as fast as it ran through a spout leading to an overshot wheel, operating under the same head and nearly twice as fast as through the spout of a flutter wheel. The miller had neither the means nor ability to measure it, but he did see that the wheel had a large power. Hence at that time it had an undeserved popularity.

The first great improvement made in the reaction wheel was in the addition of the scrolls or chutes shown in the preceding cut (Fig. 359.) It is said that this invention was due to an accident. A firm by the name of Parker Brothers was engaged in the lumber business and cut its logs with an old-fashioned up-and-down saw driven by a pair of wheels like those shown in Fig. 357, but without stationary guides. One day a plank fell into the open flume and was carried toward the water-wheel until the lower end caught in such a position as to perform the work of a stationary guide. The influence of this single plank was enough to produce a perceptible increase in the power. Mr. Parker was quick to detect it, and from it developed the scroll. The scroll consisted of a single spiral chute which wrapped entirely around the runner and carried the water into every part of the periphery of the wheel. It made the water-wheel, which he proceeded to manufacture and sell, the best and most successful in the market. He obtained a patent on his wheel but was unable to control the scroll.

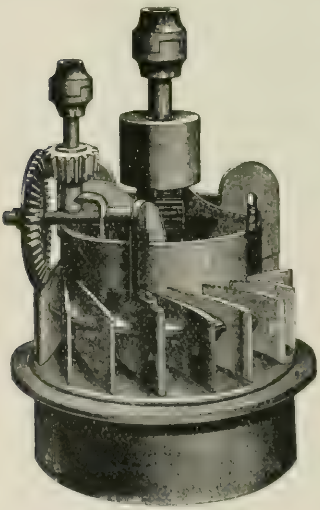

Fig. 360.—Scroll Wheel Made by John Tyler.

The scroll wheel is an exclusively American type of wheel. The accompanying cut of the Tyler wheel (Fig. 360) is a good illustration of one of the best that was made forty years ago. The cut of the Ridgway wheel (Fig. 361) shows almost the only one that is manufactured now. From 1850 to 1860 nine-tenths of the patents on water-wheels issued by the United States government were issued on scroll wheels, and the majority of water-wheels in use at that time were of that description. The runners in both of these wheels were much like those of the Risdon wheel—Fig. 355.

The scroll wheel at the present time is considered antiquated, but it was condemned and abandoned, not on account of any fault which was inherent in the principle, but because the wheels

were not properly constructed. The writer ventures the prediction that the scroll case will at some future time supersede the tub-shaped case for wheels with chutes, which is adopted by all modern builders. It is more correct in theory and experiments have shown that with wheels of medium size the water can run through the feeder of a scroll case with four times the velocity that it can run through the feeder of the ordinary case, and there will be no greater loss in power or efficiency.

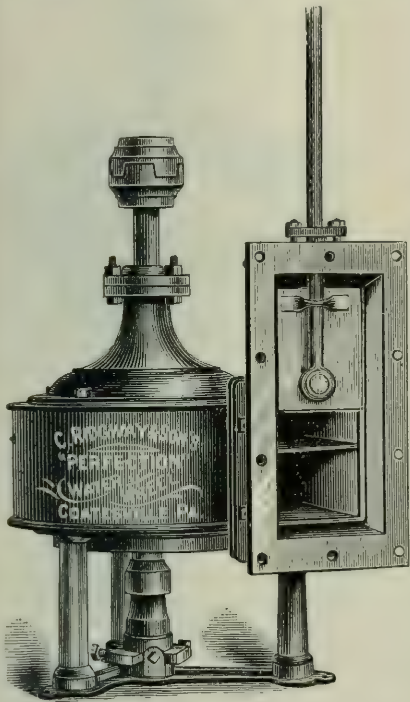

FIG. 361.—PERFECTION SCROLL WHEEL.

The water-wheel builder prior to 1860 never understood the wheel that he was building. He supposed that the water ran through the chutes with the full velocity due the fall and impinged against the periphery of the runners, which he knew ran with about six-tenths the velocity due the fall, when the water really ran through the scroll with only about 45 per cent. of the velocity due to the fall, and the wheel was running about one-third faster than the water that drove it. He did not understand the formula

$$V^2 = 2gh.$$

but he had a table calculated by that formula which he called the spouting velocity of water, and supposed that under a given head water always spouted at exactly that velocity when, in reality, it never did. But, in spite of their wrong theories, some very good wheels were developed previous to 1860.

The advantage of the scroll was that it could be built at a small expense out of wood, and the runner could be made from iron at any country foundry. Its fault was that the pressure on all sides of the runner was not the same, forcing the runner to one side and making it bind against the case. This caused a loss of power and destroyed the case. The next great improvement was to place the wheel in the middle of a large penstock and to lead the water to the runner by a series of chutes. This gave to us the American type of wheel of the present time.

One of the men who best represents this period is James

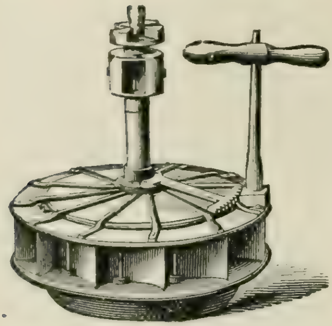

FIG. 362.—STANDARD LEFFEL TURBINE; 1866.

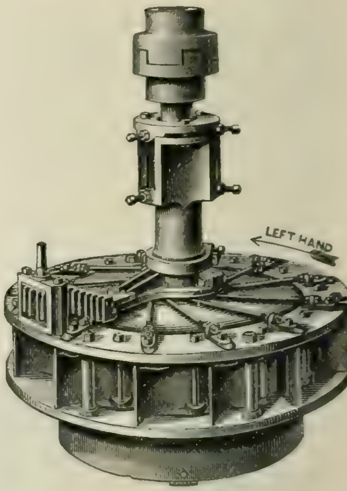

FIG. 363.

Leffel, of Springfield, Ohio, the patentee of the "Leffel" wheel. He was an ingenious mechanic of limited education, who owned a small machine shop, and became interested in the manufacture of water-wheels. His theories were wrong. He believed that the water ran through the stationary guides against the buckets and at first imparted what he called a direct action to the wheel, although in reality the wheel was running fifty per cent. faster than the water, a fact which he never discovered. He then thought that the water was caught by the runner and thrown backwards in a way that imparted a reactionary force, when in reality the wheel was driven by this last force alone. The real principle of all pressure turbines was then unknown. This principle may be briefly stated as follows: The water flows through the stationary guides with the velocity due to one-half of the fall and under the pressure due to the other half of the fall; it enters without blow or shock to the runner, whose speed at the center of the bucket is the same as that of the entering water, when the pressure of the last half of the fall forces the water back and drives the wheel from its reaction alone. This principle seems to have been unknown to early builders of the American type of water-wheel. But ignorance of this law did not prevent the success of James Leffel. He had a miniature testing flume for testing wheels 10 inches in diameter. It had glass sides through which he could see just how the water flowed. He had a Prony brake and diminutive weir by which he learned the power and capacity of his wheel. He experimented upon small wheels 10 inches in diameter (see Fig. 362) until he had one which he considered perfect, (see Fig. 363) and then he had the good sense to stick to it and not be diverted from it. He made every size exactly similar to that 10-inch wheel upon which his experiments were made. He had always the same number of guides and the

same number of buckets. The center of each curve was at exactly the same place, and the radius of the curve was exactly proportional to the diameter of the water wheel.

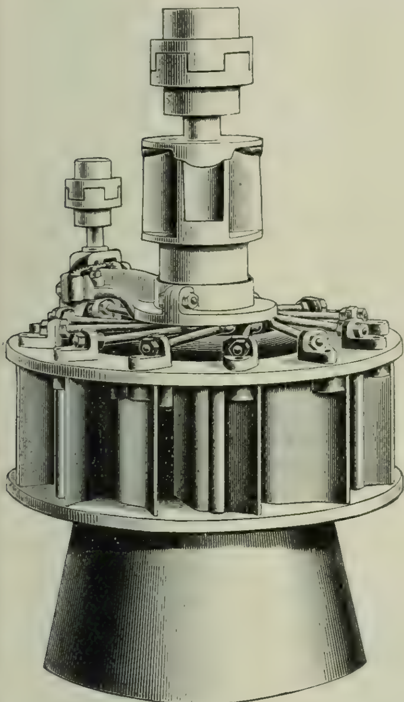

FIG. 364.—SAMSON LEFFEL TURBINE, 1898.

The capacity of each pattern was just one-third more than that of the pattern which was next below it in size. His 26½ in. wheel was of just twice the diameter of the 13¼ in. wheel, and the 6⅝ in. wheel was of just one-half its diameter, and so there was an accuracy of proportion which was before unknown. If some of the designers of our modern types of wheels, which are constructed on very complicated principles, had more of the common sense of James Leffel and made fewer changes there would be fewer disappointments. Even the number of buckets in our wheels of today cannot be changed without altering the distribution of water in the draft-tube and the percentage of the wheel. James Leffel, like few others, died when his work was done. He left his well developed invention in the hands of able men who appreciated it and knew how to sell water-wheels, and the profits from it have exceeded $2,000,000.

The greatest work done by James Leffel was the introduction of the short-draft tube carrying the bridge-tree which supports the step and shaft, he being the first to make use of this. It prepared the way for the water-wheels of increased power and capacity which are exclusively used at the present time. In these the draft-tube performs the function of the Boyden diffuser and saves the momentum and power that remains in the water after it has passed through the wheel. Experiments recently tried by the writer on the same wheel, first with and afterwards without a draft tube, showed a difference in power of 15 per cent in favor of the draft-tube.

The next great improvement in American water wheels was brought about by James Emerson, first of Lowell, Mass., and afterwards of Holyoke, Mass. The ordinary miller of that time

had only crude and inaccurate methods of measuring power and water, and of judging the efficiency of his water-wheel. He was easily deceived by unprincipled agents. Scarcely any wheels were giving more than three-fourths the power claimed for them by their makers. The majority of builders claimed that their wheels gave the same efficiency at every stage of gate, when in reality at half water they usually gave less than one-quarter of the power and wasted one-half the water. The tables showing the power developed by them were based on an efficiency of 90 per cent., when in reality they averaged 70 per cent. The most honest builders overrated their power and efficiency one third. It is difficult under the most favorable circumstances to test water-wheels so accurately that unaccountable errors of ten per cent. will not occur. The writer has never known a testing flume which did not show unaccountable errors of ten per cent. until the Holyoke Water Power Co., of Holyoke, Mass., constructed its flume. This flume cost $32,000, and in it the tests repeat themselves and can be relied upon to show no error greater than one-quarter of one per cent. on any wheel of reasonable size. Twenty-five years ago the water-wheel builder had no reliable means of testing his water-wheels. Unprincipled men took advantage of this and forced inferior articles upon the market. It did not pay to make a good and honest article. The man who overcame this trouble was James Emerson.

He was a man who was well fitted for the work which he was called upon to do, although of limited education. The writer considers that much of the credit for Emerson's success is due to his daughter, a young woman of rare intelligence and mathematical ability, who held a position in the office of James B. Francis, the eminent hydraulic engineer, then agent of the Lowell Water Power Co., where she learned to calculate water-wheel tests, and encouraged her father to purchase an old testing flume of the Swain Turbine Co., and assisted him in his work. She attended his tests, helped him to obtain and keep the records, and calculated the results for him.

Mr. Emerson made good use of his start. He was an iconoclast, which was what the art needed. He would have made a good detective and enjoyed exposing a fraud. He was very severe toward all water-wheels which had not given good results in his testing flume, and did not hesitate to advertise them as frauds. The influence of these tests upon honest water-wheel builders was marvelous. It paid then to construct a good turbine. The first water-wheel constructed and taken to his flume by what is now one of the largest and strongest companies making water-wheels in the west, gave only 67 per cent efficiency, although they honestly believed that it would give 85 per cent. When they discovered their error they began experimenting and improving their wheels until they obtained records of more than 90 per cent efficiency in his flume. A similar improvement wa

made by all the leading firms engaged in the business. The effect of his tests in introducing the best form of water-wheels was remarkable, and a complete change in the styles of wheels was perceptible. Mr. Emerson devoted himself to this work for ten years and then sold his testing flume to the Holyoke Water Power Co. By that time the business of testing water-wheels was so well developed that they constructed a very superior flume and employed a well trained and educated corps of engineers who have conducted this work in an admirable way. The former uncertainties of the testing business have passed away, and it is now a pleasure to watch a test and to see how unerringly it shows a correct form or design.

The improvements which have been developed by the testing flume have increased the power and capacity of water-wheels so that now a wheel of a given diameter does three or four times the work that one of the same diameter would have done twenty-five years ago. This reduces the cost and gives a faster and better speed. It could never have been done without the constant use of reliable tests. It is said that the Holyoke Machine Co. spent $75,000 in developing their Hercules wheel. They certainly devoted years of work and hard study to it and did not hesitate at any reasonable expense in accomplishing the desired end.

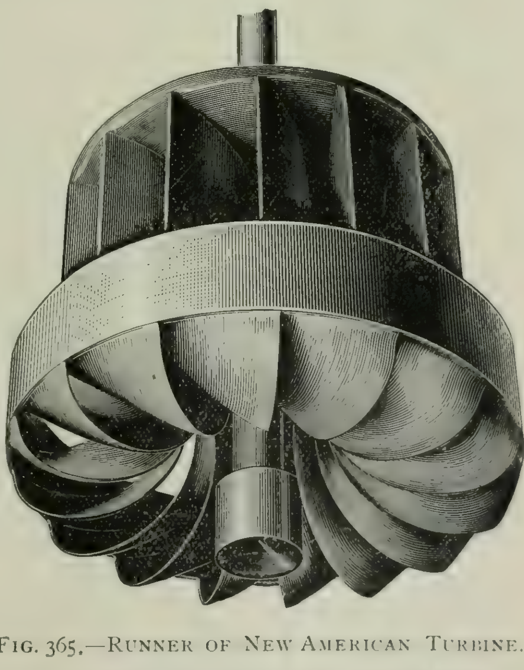

FIG. 365.—RUNNER OF NEW AMERICAN TURBINE.

(This runner gives three and one-half times the power of the Risdon Runner, Fig. 355.)

There are two difficulties which must be overcome in order to carry a large quantity of water through a water-wheel of a given diameter, and in order to obtain large power from it without loss of efficiency. The first is to save the momentum which is contained in the rapidly moving water. If the flow of water is trebled through a hole or water-wheel of a given diameter, nine times the force is lost in the departing water because the

force varies as the square of the velocity. This force is saved by the use of a large draft-tube. After the water is discharged from the runner it is distributed through the large area of this draft-tube and hence must move more slowly, because the velocity varies as the area of cross section through which the water passes, and it is passing through a greater area. If the diameter at the bottom of the draft-tube is 50 per cent greater than the lower diameter of the wheel and the water has the same vertical velocity throughout the bottom of the draft-tube, then there is only one-fifth the momentum in the water because this force varies as the fourth power of the diameter, and five is the fourth power of one and one-half. This increase of power has required a great change in the draft-tube of water-wheels, which can be seen by comparing the draft-tube of the standard Leffel wheel (Fig. 362), and of the Risdon wheel (Figs. 354 and 355), with that of the Samson (Fig. 364), and the Victor (Fig. 351.)

It has also been found that the water should be so thrown from the runner as to be evenly distributed throughout the draft-tube, and that it should have essentially the same vertical velocity at every part of the bottom of the draft-tube when it passes out of it. Since the essential work of the draft-tube is to save the high momentum with which the water leaves the wheel by sucking in more water through the wheel, and this requires the same velocity at all parts of the draft-tube, it is necessary that the runner should be so constructed as to distribute the water evenly at this place. (See Fig. 365. Runner of New American Turbine.) This requires a more perfect water-wheel than was used in the old days of slow velocities. Few water-wheel builders seem to understand these principles. Their results are entirely empirical, and the testing flume is their only guide. We now place Pitot tubes in the draft-tube to learn just how the water is distributed and how perfect the suction is; that was useless when the essential principles of such water-wheels were not understood.

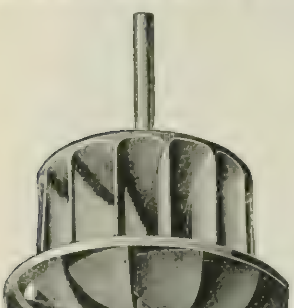

FIG. 366. OBENCHAIN'S LITTLE GIANT.

The history of this development is that Knowlton & Dolan, of Logansport, Ind., were building a runner of peculiar construction under a patent issued to Matthew and John Obenchain. It did not discharge water like the Risdon runner (Fig. 355), which represents the popular type of water-wheel of that period, but discharged part centrally and part vertically and part centrifugally. It was erroneously considered that three times the water would pass through a water-wheel and three times the power be obtained if it discharged in three directions instead of one. John B.

McCormick, of Brookeville, Pa., became familiar with the Obenchain runner, and was able, with financial assistance, to place ten wheels of this type in cylinder gate cases and take them to Holyoke to be tested. One of them gave not only three times the power of the ordinary wheel of that period, but it gave the following percentages of efficiency: At full gate, 83 per cent; at seven-eights water, 86 per cent; at five-sixths water, 89 per cent, and at one-half water, 73 per cent. It was afterwards learned that the tests could not be repeated and that the results were obtained by one of those peculiar and unaccountable freaks to which that particular testing flume was frequently liable. The highest average of the other nine wheels was only 75 per cent. The results were contradictory, but it was enough to awaken the public to the fact that the power of a water-wheel could be enormously increased by proper construction. The Stilwell & Bierce Co., of Dayton, O., were the first to take up the matter and employed Mr. McCormick under a contract by which he guaranteed to produce wheels of a certain efficiency. This he failed to accomplish, and his connection with them soon terminated, but E. R. Stilwell took the matter up where McCormick had left it, and produced the Victor wheel (Fig. 351.) The Holyoke Machine Co. next took up the enterprise and with Mr. McCormick's help produced their Hercules wheel. Now every water-wheel builder is making use of this discovery.

While this improvement in capacity and power was being developed by the use of the testing flume, another great improvement was being developed in spite of the opposition of Mr. Emerson—namely, the mounting of wheels on horizontal shafts. The first wheels of the American type were mounted in this way, as shown in Fig. 359, but they were not economical of water. Draft-tubes were then made of wood, and were liable to leak, hence they were considered treacherous and unreliable. Millers were afraid of them. It was the use of iron draft-tubes that made draft-tubes practicable, and so led to the adoption of wheels on horizontal shafts. The Boyden-Fourneyron wheel (Fig. 356) controlled the eastern trade, but could not be used on a horizontal shaft; hence, by its influence it had prevented the mounting of other wheels on horizontal shafts. The country grist and flouring mill used the old mill-stone which ran on a vertical spindle, and a wheel on a vertical shaft was best adapted to that class of trade. For many years no effort had been made to mount water-wheels on horizontal shafts.

After the American type of water-wheel had proved its superiority at the Philadelphia Centennial tests and at Holyoke, the problem of mounting them on horizontal shafts was taken up and studied by several firms. Its great advantages were plain. The first reliable tests of this method of mounting were made by Mr. Emerson at Holyoke in 1879. He tried the same wheel first on a vertical and then on a horizontal shaft, and reported that the ver-

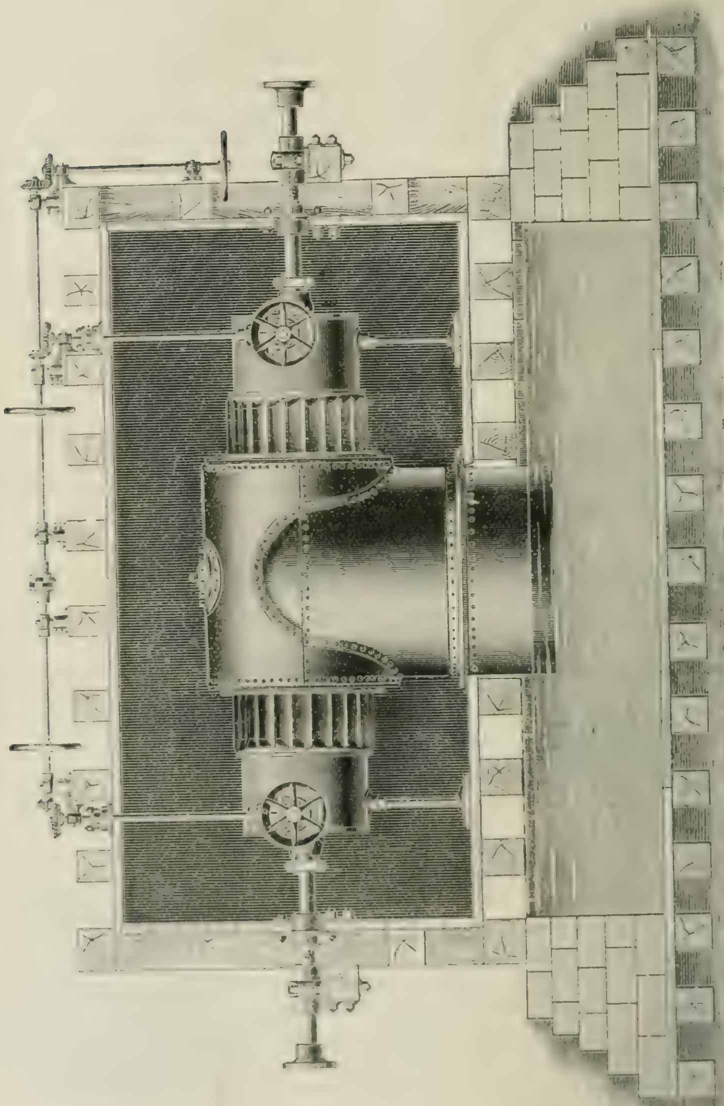

FIG. 367. PAIR OF WATER-WHEELS MOUNTED ON A HORIZONTAL SHAFT.

tical mounting gave 15 per cent more power than the horizontal in proportion to the amount of water used. Recent reliable tests in the present Holyoke testing flumes have reduced that loss from 15 per cent to one per cent, which is more than compensated for by the saving from not requiring bevel gears. Mr. Emerson's test

prevented some of our best firms from using the horizontal mountings, but it did not prevent all. The most notable exception was the firm of T. H. Risdon & Co., of Mt. Holly, N. J. They were firm believers that this method of mounting was correct in principle, and had lost faith in the reliability of Mr. Emerson's tests. They had a small testing flume of their own, and in it they tried the same wheel on both a vertical and horizontal shaft. It gave

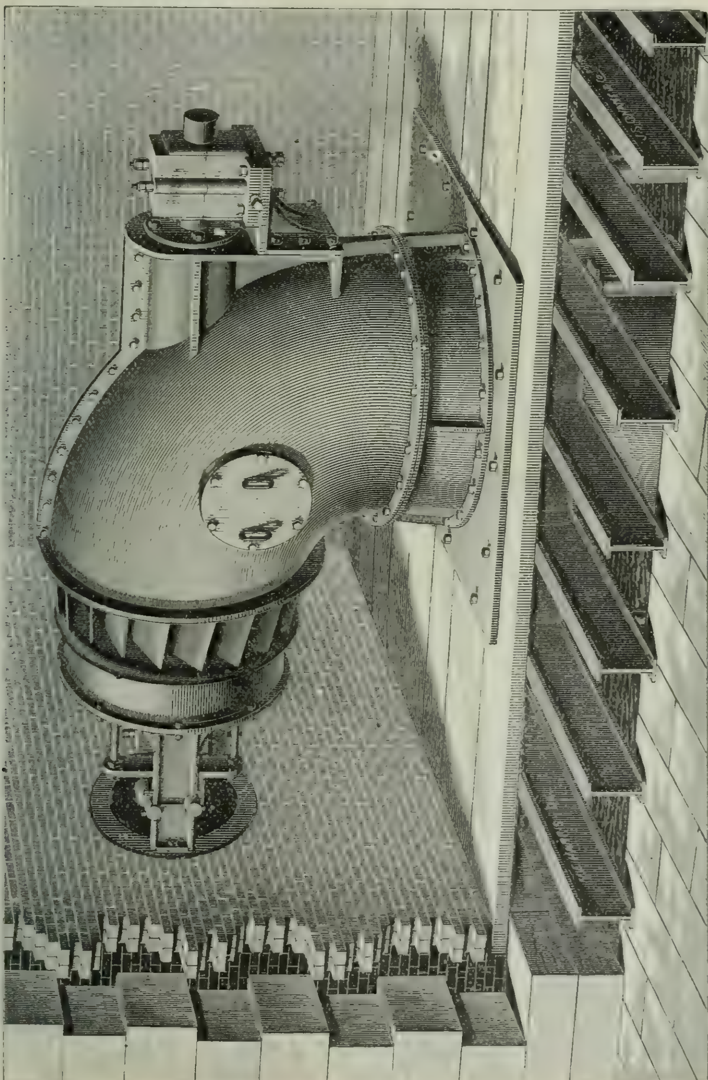

FIG. 368.—TURBINE WHEEL ON HORIZONTAL SHAFT IN STONE FLUME.

the same horse-power and essentially the same percentage of efficiency under both conditions. They used a large draft-tube, in which the water flowed at the slow velocity of one foot per second, but the water washed the air out of it after it had flowed through it five minutes, showing that the principle of the draft-tube was correct.

This test satisfied them and they immediately began to recommend the horizontal method of mounting. They were in a position to be independent of the Holyoke Testing Flume and of Mr. Emerson. Six wheels of their design had shown over 90 per cent efficiency. They had won the competitive tests at the Cen-

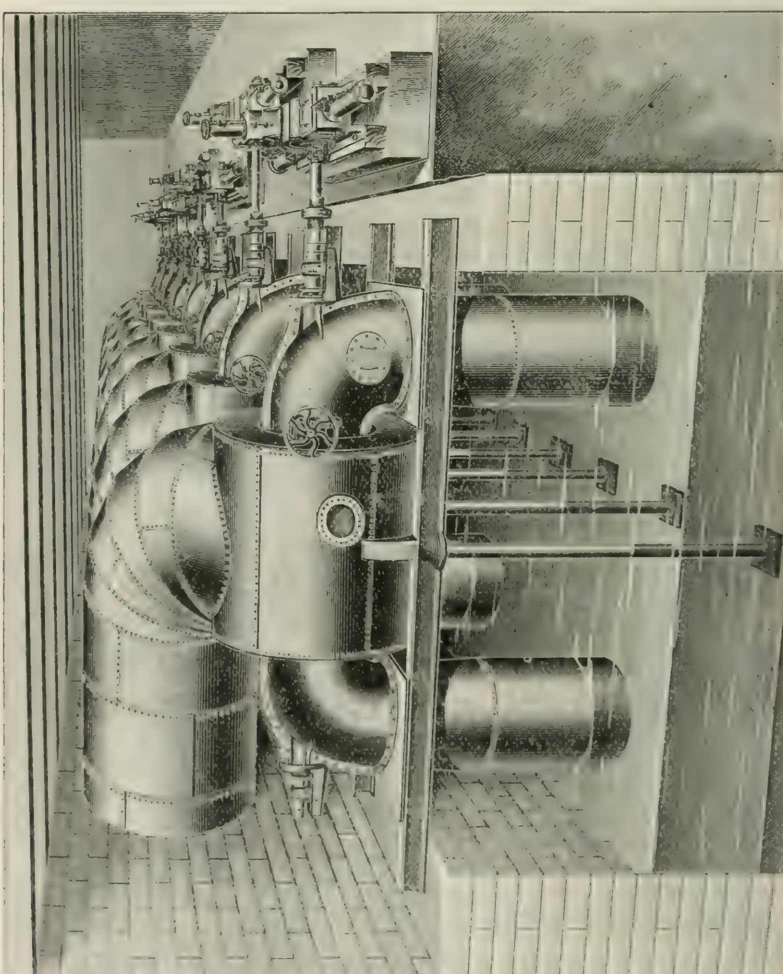

Fig. 59. Seven Pairs of Water-Wheels Driving Pulp Grinders.

tennial Exposition in 1876; they had a good reputation as engineers, and in fact the opposition of the Holyoke authorities was an advantage to them because it kept other leading firms from adopting horizontal mountings, and thereby gave them a virtual

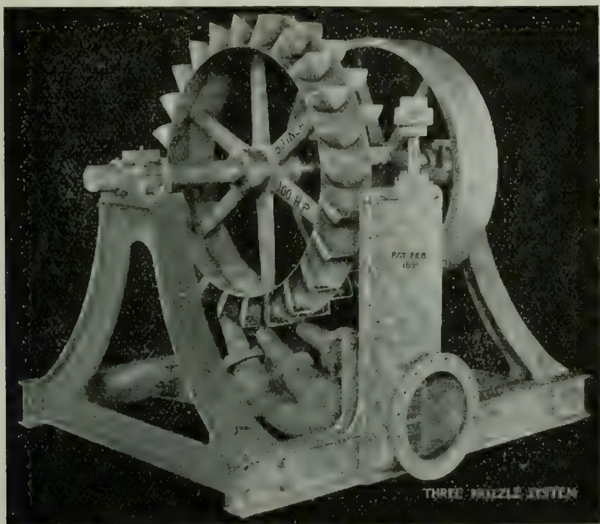

FIG. 370.—CASCADE WHEEL.

monopoly in the East. But they could not long keep it to themselves, and now three-fourths of our water-wheels are mounted on horizontal shafts.

No reliable tests of such mountings showing a high percentage of efficiency were made until 1897, when the Holyoke Testing Flume was so remodeled as to be able to test them, when the loss from this method of mounting was found to be very small while its mechanical advantages were great.

America has a right to be proud of its water-wheel. It is far superior to the types developed in other countries. We have adopted it, not through pride or from independence, but because it is the best. The great difficulty with the old style of French Jonval was that no way could be found of attaching a good gate to it, which would regulate its speed or control the water as it passed through it. The gates of the American type move twice as easily and use the water twice as economically at the part gate. The Fourneyron wheel, fifty years ago, was adopted in our best mills, but they all discard it now. It runs too slowly. It cannot be mounted on a horizontal shaft. Leaves or anchor ice will clog and stop it. The writer well remembers how the old Boyden-Fourneyron wheel in the machine shop in which he worked in his

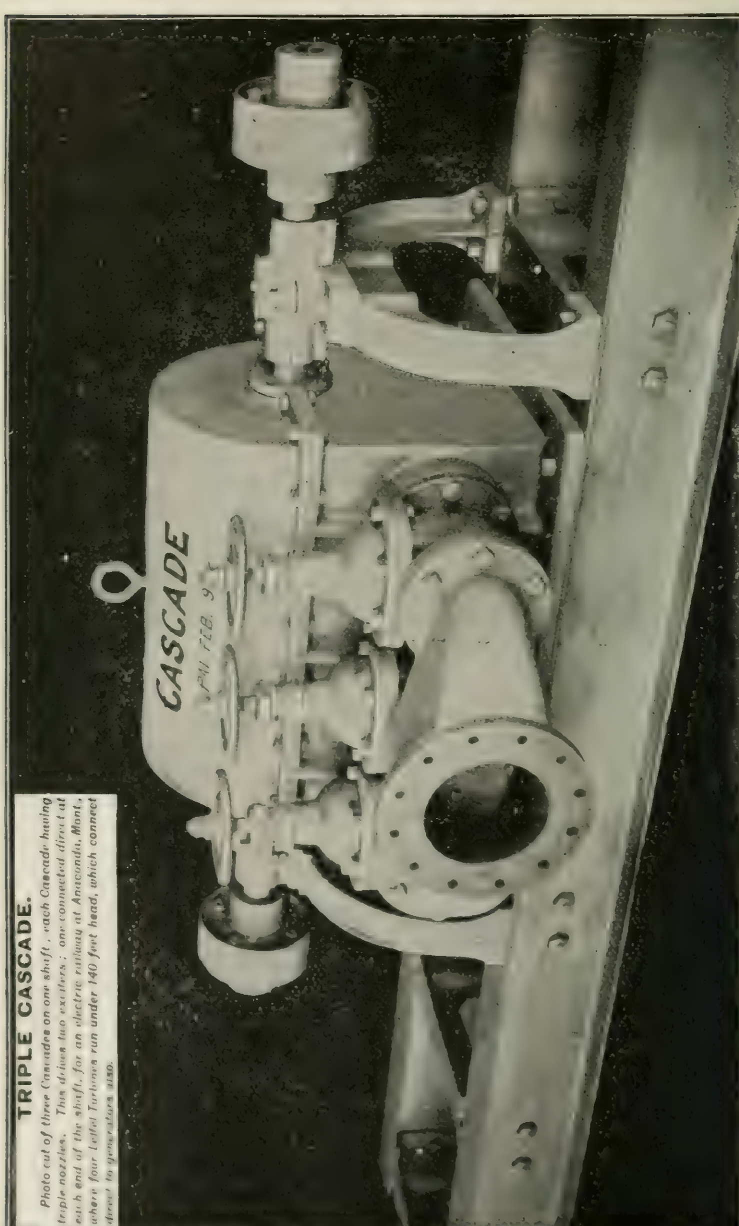

FIG. 371.—TRIPLE CASCADE.

early days would be clogged by leaves or anchor ice in spite of the best of screens; until the head-gates were closed, the shop was stopped, 500 men prevented from working and the wheel was cleaned out. Such wheels cannot be sold now. In order to put a new step into the wheel, planks must be dropped into the tail-race, or back-gates closed, the pit must be pumped out by steam power or hand until the step could be reached. Now the wheel is placed about ten feet above the tail-water, where every part is accessible. The old gears are gone and the power is carried by a straight belt from the shaft of the water-wheel to the work. Everything moves faster than fifty years ago. Shafting, machinery, railroad cars, steam engines, all have rapid speed. The American type of water wheel is capable of a high speed, and thereby well fitted to the times.

A history of American water-wheels would not be complete without mentioning the American type of jet wheels. These have been developed here more than in foreign countries. Their peculiarity is that the water is discharged into them through a nozzle like that of the hose of a hydrant. They are better adapted to high falls than the pressure or ordinary turbine because they can be made larger in diameter, and also because, when of the same diameter and operating under the same fall, they travel at only one-half the speed of the ordinary pressure turbine. Under a fall of 100 feet the average small pressure turbine will make 1,500 revolutions per minute, while the jet wheel, like the above cut, will make only 300. Hence the small pressure turbine soon wears out and loses its efficiency, while the jet wheel retains it. When both are new and in good order the jet wheel has a higher efficiency than the small turbine. The latter would rarely hold an efficiency of 70 per cent in the testing flume. It would be less economical of water than the overshot, although the turbine of medium or large size is usually more economical of water. The jet wheel of proper construction is capable of a high efficiency. Many of them have given an efficiency of more than 85 per cent; several of them have given more than 90 per cent. But the experience of the writer in testing them is that they do not maintain that high efficiency. Different sizes show different results and do not repeat as well as the pressure turbine. A rusty nozzle, buckets with blunt cutting edges, setting the nozzle at a wrong angle, and other errors, will easily reduce their efficiency 10 per cent. But, even then, they are more economical than the small turbine.

The principle of these wheels is different from that of the pressure turbine. The water runs through the nozzle in theory with the velocity due to the entire fall, and in practice with about 98 per cent of that velocity. The wheel should run by theory with one-half the velocity due to the fall, but in practice it gives its best percentage of efficiency when running about 42 per cent of the velocity due to the fall. The water should be thrown back

by the wheel with a velocity equal to the difference between the two velocities, which in theory is one-half the velocity due to the fall. Then, if the wheel moves forward with one-half the velocity due to the fall and the water is thrown backwards from the wheel with one-half the velocity due to the fall, the two will equalize each other and the absolute velocity of the water will be nothing, and all the force of the water will have been used in giving power to the wheel. The water enters the wheel without pressure and the reaction is obtained from momentum alone.

In the ordinary type of turbines which have been previously described, half of the fall is used in carrying the water through the stationary chutes or guides and half in carrying it through the wheel. The wheel travels with the velocity due to half the fall. The water enters the wheel at the same velocity without shock or disturbance. Both are traveling at the same velocity. In the runner the water operates under the pressure of half of the fall. The pressure of the last half of the fall drives the wheel by its reaction. The velocity due to half the fall is seven-tenths that due to the whole fall and 40 per cent. more than one-half that due to the entire fall. In practice the periphery of the pressure turbine travels with about 78 per cent. of the velocity due to the fall, and the jet wheel travels with 42 per cent. the velocity due to the fall. Hence the pressure turbine has nearly twice the velocity of the jet wheel of the same diameter operating under the same fall. For heads of over fifty feet, where less than 100 horse-power is required, the jet wheel runs slower and is better than the pressure turbine. The pressure turbine must be fed regularly on its whole perimeter or it will lose its efficiency, since the pressure of the water in the bucket is the source of the entire power. But the water is not acting under pressure in the jet wheel and it can be fed on the entire perimeter or on any part of it. The jet wheel must always run in air and no draft tube can be used with it.

The credit for the success of this American type of the jet wheel belongs to the Pelton Water-wheel Co. of San Francisco, Cal. Mr. Pelton saw the great need of a water-wheel suitable to the high falls and limited quantity of water of many locations on the Pacific coast. This was specially true of smelting and mining plants. The amount of power required was small. The little turbines which had previously been used ran too fast; their bearings would heat and wear out. They were not durable and they clogged easily. Pelton was a mechanic of limited education but a genius. He knew nothing of brake and weir tests when he originated his wheel, but he knew how to build a water-wheel which satisfied the wants of his customers. He was first engaged as a mill-wright to design some water-wheels for high falls. They were found to be superior to any others for this work. Capitalists became interested and helped him. The enterprise was well managed and large numbers were sold and gave good

satisfaction. Wheels of the same character are now built by other firms.

DISCUSSION.

Mr. Feldman: I would like to make a few remarks in regard to the Fourneyron type of turbine. It was introduced in this country by Mr. Boydon, of Massachusetts, who made some improvements in its design. The wheel is of the radial outward-flow type.

Being a reaction turbine it works efficiently only when the buckets are full of water. During the regulation of its speed, the supply of water is being decreased, then the buckets would not be full of water and the efficiency of the wheel thus diminished. To overcome this difficulty the turbines are built several stories high. The turbines used by the Niagara Falls Power Co. are twin wheels, three stories high, of the Fourneyron type, designed by two Swiss engineers.

President Noble: Can you give us some idea of the tests by which that wheel was supposed to be proved superior ?

Mr. Feldman: The Niagara Falls turbines are developing .5000 effective horse power each.

Tests have shown that their efficiency is about 7.5 per cent.

XXX.

*MECHANICAL PLANTS OF LARGE BUILDINGS.

By Dankmar Adler, Mem. W. S. E.

Read March 16, 1898.

It is only within a very few years that the general public has begun to realize the extent and the importance of the machinery plants, without which our large business buildings of every type could not be occupied or used. Business men could not bring themselves to believe that the engineering equipment necessary for promoting the comfort and health of the permanent and transient occupants of a large business building could equal, much less exceed, in importance, magnitude or difficulty the mechanical plant of an ordinary factory. In those days the trusted engineering expert was for each business man interested in a steam plant his own "engineer," so called because he periodically opened and closed the throttle of an engine, which he oiled and cleaned and looked after generally, when not occupied with the shoveling of coal or the removal of clinker and ash. But as each of these so-called "engineers" rarely had more than his own observations and experiences to fall back upon, and as the collated records of the world's work and the comparisons, researches and conclusions based thereon were to him a sealed book, his mental horrizon was painfully narrow. If such men were enterprising and progressive, they were apt to favor the use of expedients before tried by others and found impracticable, or if, as was more generally the case, they were obstinately and honestly conservative, they opposed innovations upon the practice known to themselves with a doggedness of purpose which generally carried conviction to the minds of their employer. As a consequence the heat and power plants of the business buildings erected in the sixties, seventies and early eighties, were exceedingly crude and wasteful. Sixty pounds was the maximum steam pressure used. It was always safe to assume that either boiler or stack, or both, were too small. Exhaust steam was always blown into the air, barrels of water of condensation were run into sewers. Pipes were irregularly, ignorantly and arbitrarily proportioned, and there was scarcely a time during the period of operation of steam-heating apparatus when the ear was not assailed by sounds reminding an old soldier of the transition from lively skirmish to actual battle.

It was a blessed era for contractors. Their specifications and their planning became the final refuge of the coal shoveling engineer. The contractor was bound to have his own way, for he claimed that otherwise he could not be held responsible for results. And then after the contractor had had full swing and, as

was often the case, the results were not satisfactory to the employer, that person was an ungracious scamp, a blasphemous railer at the dispensations of Providence, a derider of the Laws of Nature; the contractor certainly couldn't be expected to make warm weather at a time when it pleased Providence to send cold, or to make water run up hill, or to make air and water occupy the same space at the same time.

But throughout all these years education through adverse experiences of clients, architects and contractors was going on. By the end of the eighties there were clients who had learned that valuable knowledge in the field of steam, mechanical and electrical engineering might be found in the possession of men not clad in overalls, and that a soot and oil stained hand and face were not essential concomitants of the possession of the kind of knowledge which is necessary for the proper proportioning of first cost, and of cost of maintenance and operation to the general requirements of the machinery plant of a given building.

Some architects had learned to note not only cubic contents but also the exposure to radiation of rooms to be warmed, and to proportion radiators accordingly. They had learned that it was possible to ascertain the work to be done in each of the various pipes, and that their dimensions might be made to bear certain relations to such work, and last but not least the relations of output of steam to heating surface and grate surface, and the relation of the latter to stack dimensions had come to be understood.

The same educational influences were at work with the contractors, and before the beginning of the last decade of this century the work of the professional engineer was more or less in evidence as a component part of the design of buildings containing heating or ventilating apparatus or making use of mechanical or electrical energy in any form.

Electrical energy; electricity, that was a new complication which, while ultimately a stimulus to far-reaching progress, was at first a most serious retardent of progress in the application of engineering science and skill to the design and construction of buildings. Here was an occult and mysterious force expected to work miracles and obeying only the commands of wizards and magicians initiated into the mysteries of its manifestations. *Science, obedience to natural laws, and calculable by the rules which govern the operations of all mechanism! Faugh!!* Had not men of science at one time scoffed at the possibility of accomplishing the very things which were now revealing themselves to our wondering gaze? Had not the evidence of these same alleged natural laws, of these same so-called mechanical principles been invoked to prove the correctness of the scientific negations of these realizations of dreams of Arabian Nights? As the performance of the newly discovered power seemed to surpass the wildest possible flights of the imagination, it seemed that naught but hyperbolic statements might be believed with regard to all connected with its

application to the service of any building. The sober statements of adepts in mechanical and steam engineering were scoffingly set aside as the envy-inspired utterances of men who felt that their vocation was vanishing, or decried as the wail of those despairing over the inevitable supplanting by electricity of steam and of steam driven mechanisms. For a time the field of engineering design was in possession of the salesmen of producers of electric apparatus, and he was the best salesman and, therefore, the best engineer who could promise the performance of the most incredible marvels. With the new industry had come a vocabulary of technical terms, with reference to which the general public was in total ignorance, while its shibboleth had been but partly mastered by the engineers of the day. But the salesman, filled to the brim with the words and phrases of the glossary of electrical technics, sought to drown the reasoning faculties of his hearers in torrents of terms and phrases whose significance was not at all clear to the speaker and still less so to the hearer. Contracts after contracts were made without any clear understanding as to their meaning, except that in every case there was on one side an expectation that by the introduction of electricity the heretofore unattainable would be attained, while on the part of the other party there was the determination to transfer a substantial share of the first parties' money to the coffers of the owners of patents for systems of electrical all sorts of things, coupled, of course, with the hope that a kind Providence might bring about the fulfillment of the expectations aroused in the mind of the purchaser of electrical apparatus.

By and by this condition of things became unbearable, and the initiative in a reform movement was taken when contracts for electric installations made their appearance containing a clause by which contractors were absolved from responsibility for fulfillment of salesmen's representations and promises unless such were specifically incorporated in the contracts. Up to this time purchasers of electric installations had "held up" the contractors because of their inability to accomplish what their salesmen had promised. Now, contractors "held up" purchasers by means of a contract composed of ingeniously conceived and carefully limited technicalities, erected upon a preparatory foundation of vague, indefinite and, all promising salesmen's generalities and promises.

It may be asked, where during all this period, covering nearly ten years, was the engineer? At first he didn't exist, at least as far as the earlier electric installations were concerned. The science of electrical engineering had first to be developed before electrical engineers could be educated. The irresponsibility and wildness of the claims made by the owners of patents for electric apparatus disgusted and estranged the educated mechanical engineers. The production and application of the electric current seemed enveloped by fantastic clouds of mystery which had been created by the irresponsibly and irrespressibly

valuable salesmen, styled engineers by their employers. Elec-crical engineering was deemed but little removed from the black art and assumed to be wholly empirical. It was understood and practised by the Wizard of Menlo Park and by a few of his disciples. Its mysteries were beyond the ken or reach of a mere matter of fact creature of formulae and figures like the mechanical engineer for whom there would be no room on earth in the good time coming, when electricity would supercede steam and water, when the unchaining of more or less lightning would perform all of the world's work.

The persons interested in the commercial exploitation of electrical patents and processes had in the purchase of these patents, had their own imaginations worked upon, and proceeded in good faith to sell attempted realizations of the fanciful dreams which they had bought. But before long they learned to know the dangers which attend obligations to deliver many undefinable imaginary somethings and then came the consciousness that perhaps it might be well to find persons who could define and limit the things to be accomplished by an electrical installation. And this was the Genesis of the electrical engineer, whose function was for years the effort to reduce to terms profitable to his employers the fraction $\frac{\infty}{\infty}$ in which the numerator represented the expectations excited in purchasers of electric installations of patented electric apparatus by the weirdly plausible pseudo scientific jargon of the salesman, while the denominator represented the passionate longing of the owners of these patents for dividends upon the untold millions of capitalization represented by cost of original patents by experimentation and litigation, and last but not least by irrigation.

Eventually the managers of the great companies which had absorbed the patents for so many electrical appliances and processes learned that the symbol, ∞ however befitting an incantation or a spiritualistic seance, is out of place in any part of any business transaction, and the services of the engineer were invoked to determine in finite terms of exact science, the conditions of promise as well as the work of fulfillment of their various contracts with the public.

Following this recognition of the value of the services of the electrical engineer as an adept in an exact science rather than as a wizard and an invoker of dreams, the technical schools of two continents vied with each other in turning out graduates who were rapidly absorbed by the ever widening fields opened in every branch of engineering activity in which our skypiercing business buildings occupy a most conspicuous position.

Emerging from the stupor and the trance-like condition into which the advent of electricity and the Saturnalian clamor of its votaries had thrown them, owners and architects of buildings and the engineers associated with them, at last felt free to treat the

lifting of water, of chattles and of persons, the warming and ventilating as well as the artificial illumination of their buildings, as corellated interdependent problems, capable of solution by scientific and businesslike statements of equations of which the world's store of observed, recorded and collated facts are on one side, the peculiar conditions of use, service and environment of the building in hand on the other, and a maximum of commercially efficient economy is the solution sought for.

While this statement of the situation is, and probably will always remain true, the elements of the equation are ever shifting. On the one side the world's store of knowledge is continually increasing, and the relative importance of the observed and recorded facts changes with each new discovery. So also is the other side constantly being modified by changes in the occupations and the demands of men and of business and by the desire to utilize fully the advances made in man's power of command over the elements and forces of Nature, and, finally, we are forever raising the standard of that maximum of possible attainment by which the allowable limit of error in our solution is determined.

The task set by their physical and psychic environment for owners, architects and engineers of buildings is therefore not by any means an easy one, even if only the ordinary and indispensable requirements are considered.

The following requirements for satisfying which mechanical appliances and apparatus are essential will be found in all business buildings and in every structure of many stories.

It is necessary to maintain at a moderately warm and approximately uniform temperature the interior of every building in which human beings spend any considerable portion of their time.

Water supply is required upon every floor of almost every building. In many instances hot as well as cold water must be so supplied.

In every case appliances are necessary for raising to and lowering from the upper stories goods, furniture and persons.

In every building means must be provided for artificial illumination.

Frequently mechanisms of various kinds must be driven, and occasionally artificial ventilation must be provided.

Heat, Light or Power, or any two, or all of these may sometimes be obtained from extraneous sources, but in the case of buildings of magnitude or importance, can almost invariably and must generally be generated by apparatus especially installed for each individual building. The number of places where an external supply of heat is available is small, but there are numerous and constantly multiplying opportunities for procuring light and power from sources outside of any particular building. The efforts made by the purveyors of heat, and more especially those made by the purveyors of light and power are vigorous and all pervading. The

question as to whether or not to yield to their importunities is being forced at every possible opportunity upon owners, architects and engineers of buildings.

In places where steam for heating and electric current for driving mechanisms and for illumination can be obtained from external sources at moderate cost, it will generally be found that the saving of space, economy in labor bills, avoidance of heat in summer and freedom from internally produced dust and soot at all times bespeak favorable consideration for the external vender of heat, power and light, the exceptions being only those very large structures whose requirements are so vast that their heat, light and power stations can vie in economy of operation with the public station and whose service is so important that the risks of interruption in transmission from distant stations cannot be tolerated.

Second. Where steam can be had from the outside, but not electric current for power and light, the decision may depend upon the extent to which the two last mentioned are to be used. With small and intermittent use of power-driven mechanisms it may be better to drive a small engine with steam from outside than to produce it within the building. If a boiler installed within a building is used only as a generator of steam for heating purposes it will generally be found better, for reasons which will be hereafter given under a different head, to procure steam from a constant and never failing source of supply, than to generate it within the building.

Third Where there is no external source of steam supply, but where electric current can be introduced from without, the problem becomes more perplexing. One condition is ever present in the colder portions of the temperate zone. It is the necessity for circulating steam for warming purposes almost constantly during four months and periodically during three months of every year. If power and light are generated within the building, the exhaust steam is available with but slight loss of heating efficiency and therefore with small fuel expenditure for circulation in the warming system. During the same period the item of furnace and boiler attendance would be increased but little, if at all, by using the boiler also as a source of power and light supply. Again in every year there are two months, and in some years three months, when artificial heat is required for but a short time each day and when sudden falls of temperature occur. At such times the presence of a constant supply of steam is a source of comfort. Where heat and light are obtained from external sources, and the boiler in the building is used for warming only, such unexpected and spasmodic periods of low temperature may come before the boiler has been started up for the winter, or after it has been shut down in the spring, or even if in operation such drop in temperature may come suddenly at any time of a warm day when the fires are banked, so that much discomfort

may ensue before the fires can be started and steam generated and circulated. And yet on the other hand it may not be possible to install a local power and light plant without occupying most valuable space, and the heating effect due to its operation in summer may produce discomforts during the whole of the hot months sufficient to counter balance those encountered by reason of absence of steam circulation during an occasional cold spell in the spring or autumn. Of course the difference in interest and maintenance charges is another element to be considered. Then also there is the question before referred to, as to whether power is used constantly or spasmodically, in large or in small volume.

Suppose now that the importunities of the representatives of central stations have been disposed of and that the kind of installation best fitted for a building has been determined upon.

The first and most important item is the heating apparatus: Here it becomes necessary to tabulate cubic contents, exposure to points of compass, areas of windows, walls and roofs, thickness of walls, and to note the kind of occupation required, and by the aid of the excellent work done by way of experimentation by German engineers, translated and condensed for American practice by my friend, Alfred R. Wolff of New York, to determine the heating surface required in each room, and to locate the same in such manner as to be at once efficient and out of the way of furniture. Then comes the determination of pipe dimensions, and incidentally with this, whether there is to be a one or a two pipe system, and whether the horizontal distributing mains are to be at the top or at the bottom. All the better modern practice tends to the one pipe system, and in a very high building to overhead distribution. It may be taken for granted that the working pressure will be five pounds or less, and that the piping must be such as to allow of circulation at a pressure of not more than eight ounces. Where steam is used for driving engines, the exhaust steam must be utilized; there must be a steam storage tank, which serves as a source of supply to the heating pipes, independently of the boiler.

It is a fact, the existence of which must be regretted, but which for all that is an essential consequence of unavoidable conditions, that boiler and engine rooms will be located only in the cellars of business buildings. In Chicago, up to within about eleven years ago, the impossibility of draining basements below sewer level made it impossible to use large boilers or deep fire boxes or ash pits. The introduction of the automatic sewage ejector has made it possible to secure drainage at any desired depth below city sewers, and makes it possible to design boilers and their settings without much regard to the space to be occupied vertically. By thus lowering the boiler and engine room floors, the boiler and pipes can be kept at greater distance from basement ceiling, and thus the transmission of heat through the floor may be minimized.

The discussion of types of boilers and settings is in itself a subject for a separate paper, and will not be taken up here.

As to smoke stacks, my favorite practice is to enclose a cast iron or steel pipe in a shaft of brick or tile, using the latter as a ventilator for the boiler and engine room.

Next in order of importance is the elevator system.

The old fashioned steam elevator, while perhaps the most reliable of all known hoisting machines, is also the most wasteful of steam.

Next comes the horizontal cylinder multi-sheave hydraulic machinery, driven by an ordinary steam pump—80° steam per H. P. hour, 50% efficiency of hydraulic machines, next the vertical cylinder multi-sheave hydraulic machine, a little higher in economic efficiency of motion, but also dependent on a wasteful pumping apparatus (the same may be said of the water balance elevator) of either of these types are all the elevators erected up to within a very few years ago. This however must be said for them, they are safe, easy of control and smooth of operation—but they are fearfully and wonderfully wasteful of fuel.

The first reform made was one that is possible only in buildings in which many elevators are used, so as to bring water consumption near to a uniform average, and thus make the use of a better pump a possibility. This was first accomplished at the Auditorium, where twenty-two elevators are run from pumps which in a continuous test run of two weeks' duration and continuous night and day work developed a duty of about twenty-eight pounds per H. P. hour.

The multi-sheave electric screw elevator shares some of the good qualities of the horizontal cylinder hydraulic elevator and also the waste of energy due to the friction caused by its many sheaves, which becomes appalling in a very high structure.

All electric elevators have this advantage over hydraulic elevators. While the latter use as much power in lifting a light as in handling a heavy load, the electric elevator makes an approximation to using power in proportion to load. The large volume of starting current required partly offsets this advantage. In elevators of all kinds counter-weighting for average loads may be made a means of increasing economic efficiency.

In small buildings with less than three elevators, or wherever the elevator duty is intermittent, the electric elevator will give better economic results, also where power is taken from an outside source.

It is, however, possible that the electrically driven centrifugal pump may restore the hydraulic elevator to universal favor and that it may make it possible to rival the directly connected, electric elevator engine in its claims to economy.

Turning now to the electric apparatus of our buildings it may be said that in determining number and capacity of generators for electric current, and of the engine by which they are driven, heed must be paid to maximum average and minimum loads and to securing a moderate reserve capacity. If electric elevators are

used they must be driven by separate generators, or a storage battery must be introduced. On the whole it will probably be preferable to couple generators direct to engines, giving the outboard bearings. Foundations of engines and generators should be separated from those of the building, and every possible precaution should be taken first to prevent vibration and noise and next to insulate all possible sources of vibration and noise from the structural members of the building.

As to water supply it will be found better to pump from an open surge tank than to follow the general practice of using a closed one.

It will always be found advantageous to have one or more shafts from the engine room to the top of the building for conveying pipes, cables, etc.

But my subject is one about which one might go on forever without exhausting its many phases. The presentation of these may safely be left to others of our members better fitted than I by education and practice in each of the many details of engineering practice which would have to be exhaustively considered.

DISCUSSION.

Prof. Feldman: I would like to ask Mr. Adler to explain the system of heating used in large buildings.

Mr. Adler: The ordinary practice is to turn all exhaust steam into a special tank proportioned to the work to be done, also to connect this tank direct with the boiler; to interpose reducing valves set so as to maintain a uniform pressure, and prevent the tank from being under boiler pressure. The distributing mains are carried to the top of the building, sometimes in a single pipe, sometimes in several, more generally in a single pipe. They are distributed there in an attic between the top story and the roof; horizontally and at convenient points, downward mains are carried and connected at the different stories with radiators. The vertical pipes are generally securely fastened in the middle so as to allow expansion in both directions, both upward and downward. The steam and return, or water of condensation, travel in the same direction; they are taken up by a system of horizontal return pipes that is generally carried below the basement ceiling, and carried to a receiving tank below the water level, where the boiler feed pumps are which pump the water of condensation back from these receiving tanks to the boiler. Of course during very cold weather, when all the exhaust steam is used for heating, and considerable live steam too, all the feed water goes from this receiving tank; no fresh water is used. However, in moderately cold and mild weather, and altogether in warm weather, the exhaust steam is blown out into the atmosphere and must be replaced by the water taken from other sources, which is warmed in

the ordinary manner through feed water heaters; very frequently the feed water heater and receiver are made in one.

The system is really very simple. It cuts loose entirely from the boiler as an immediate source of steam supply, but, starting from the steam tank, which is kept at pressure anywhere from five pounds downward, the circulation is the same as it would be in a small residence heating plant, excepting only that while in the smaller plants the circulation is from below, here it is taken from above, so as to have the steam and the water of condensation travel in the same direction.

The main thing in designing a plant of that kind is to get the pipes big enough, and also to some extent to pay attention to possible irregularities of settlement of the building. This will occur, and it quite necessary to foresee the directions in which it may possibly take place and arrange the pitch of the horizontal pipes accordingly. But apart from that, there is really small difference from the heating of an ordinary residence by steam; it is only this, that there are a great many more radiators and much larger pipes.

Mr. T. L. Condron: In the ventilation of ordinary sized halls, is it necessary to resort to other means to draw the foul air out, than the use of a ventilating space around the smokestack? Is it necessary to use exhaust fans?

Mr. Adler: In ventilating any kind of a hall it is probably best always to use pressure fans for blowing in air. The difficulty with the space around the stack is apt to be, in a building used for miscellaneous purposes, that so many calls are made upon it that there is not much chance for using it in connection with ventilating the hall; in fact, to exhaust the air from the engine and boiler rooms, possibly from a kitchen, from toilet rooms, etc. will be found a sufficient task for the space surrounding the smokestack. There is the advantage, too, in mechanical ventilation that it is positive at all times, and that both for supply and exhaust any part of the hall can be reached. I am inclined to think that there are very few halls, in this country at any rate, where sufficient care has been taken to reach every part of the hall by supply and exhaust ducts. These ducts must be large, and it is generally very difficult to make them reach to every place they ought to go. You will find, for instance, in many halls —I should say the Auditorium is no exception—that when you get to the entrances that lead from the lobbies under the main gallery, that you will find the perceptible odor of humanity. Now as long as you get that odor it is a sign that either there is not enough fresh air introduced, or not enough foul air removed, or both. I know of but one hall in this country where there has been any approximation to reaching these places that are usually so difficult to reach with both supply and exhaust system of ventilation, and that is Carnegie Music Hall in New York. I think that the distribution of air supplied and air exhausted there is

better than it is anywhere else in this country. I believe that in some of the German opera houses they have been very thorough as to that.

Mr. Condron: In the Alhambra Theatre in Milwaukee, one of the later theatres there, they allow smoking in the rear of the first floor, and I noticed the fact that none of the smoke passed out into the parquet at all, and the rear part of the hall seemed very well ventilated, the smoke being drawn back, I suppose, by artificial means.

Mr. Adler: Nothing but a system of large ducts and powerful fans would produce such an effect. I will say this about the ventilation of halls. It is a very easy matter, yet it is not so very easy, because it is generally difficult to get the money for it, and also to overcome aesthetic considerations, and the desire for getting along with the minimum space between floors and ceilings, etc., but difficult as it is to secure the installation of a good system of mechanical ventilation into a place and to get good distribution or exhaust, it is still more difficult, after a good ventilating system has been installed, to have it operated. It costs money to turn fans, and the manager of an establishment of that kind believes he does his duty, at least to himself and to his box office receipts, when he announces on his play-bills and in the dollar-a-line matter which he sends out into the world through the press, that his particular house is the best ventilated house in the world; but that is enough. It is not at all necessary to turn those fans. Why, the idea of running 40, 50, 60 to 80-horse power of electric motors, or steam engines for two or three hours of a day, or when there happens to be a matinee, for five or six hours! What, pay the enormous charges involved? It is ridiculous, absurd! We'll do nothing of the kind. It is enough to announce to the dear public that the thing is there.

Mr. Curtis: There is one thing I would like to ask about. We have in this city an ordinance, supposedly to the effect of preventing smoke. As far as I know we have nothing affecting the exhaust of steam; to my mind that is almost as necessary as the other. Now the question is this; under ordinary conditions, would it be any serious hardship to the property owner if such buildings as the one we are in or the Rookery were obliged to condense their steam instead of discharging it into the atmosphere? Of course we know that under certain conditions it is economical to condense steam; under others it is not. How is it with regard to buildings?

Mr. Adler: I should say that we are getting to an era of cheap condensing apparatus, so that I am inclined to think that there are very few cases where, during the summer months, and during that part of the year when exhaust steam is not used for heating purposes, a condenser of some kind would not pay for itself in a few years. I do not think it would work any hardship at all to prohibit the discharge of exhaust steam into the atmosphere.

That reminds me of this: During the World's Fair period I had a great many visitors at my office, which was then in the upper story of the Auditorium tower. Many of these visitors were foreigners, among them many Englishmen, and I think about every third one of the Englishmen could not understand our practice of blowing so much exhaust steam into the air. Such a thing would not be tolerated in England, they said. Then I asked them whether there were laws on the subject; they said it was not that, but that it would be taken for granted that any person engaged in any kind of business who would blow as much exhaust steam into the air as he saw from our various buildings, would be considered a little bit off intellectually, and not a fit person to trust in financial matters. A man who would be guilty of wasting as much fuel per annum as is implied by that volume of steam blown into the air, would be wasteful in other respects, and his credit was something that would be worth looking after. That was the opinion expressed to me by several Englishmen. They did not realize how extravagant Americans are in every respect.

The Chair: Do they have 95 cent screenings in that part of the country?

Mr. Adler: I guess they have. They have cheap coal, and another thing, the places where they burn ninety-five cent screenings are the ones that are most careful of their coal. The people who blow their exhaust steam into the air in Chicago are those who pay $2.50 and $3.50 per ton for coal; they are not the people who pay ninety-five cents for screenings.

The Chair: In case where air is blown into the room are artificial means used to take it out?

Mr. Adler: No, that is not always the case, not by any means. In fact there are quite a number of buildings where no effort is made to do that, it being assumed that doors and windows are not air tight, not even walls, and that it is a good thing for the room, in addition to maintaining a little higher atmospheric pressure inside of the room than exists outside, and thus preventing the coming in of cold draughts around windows, so that instead of the cold air blowing in, around and below the window, the warm air will blow out, and this is really better in small rooms and unimportant rooms. Of course in a large room you could not think of doing that because the various bodies of air, warm and cold, pure and impure, will neither get out of each other's way, nor mingle with each other with sufficient promptness. If you blow the air into a large room, and you do not take it out, you may have pure air in one part of the room and decidedly fetid air in another part. You can only get rid of the bad air by drawing it out of the room and getting it out of the way of the pure air that you are driving in. And these processes must be going on simultaneously in different parts of your room.

The Chair: About the only thing I ever knew about heating and ventilation was perhaps contained in the saying that air

is like a rope; you can pull it, but you cannot push it. I do not know if that still obtains or not.

Mr. Adler: You can do almost anything with air, I guess. That reminds me of my first introduction to the realm of scientific ventilation. I was a very young fellow, working in an architect's office at Detroit. Mr. Ruttan, probably known to the older ones among you, at that time had been employed to provide ventilating apparatus for the cars of the Michigan Central Road, and our office was to make his working drawings, and I was set to work at them. The first thing Mr. Ruttan asked me was, "Well, young man, will hot air, if left to itself, rise or fall?" "Oh, it will rise." "Well, will it? Does not the law of gravitation apply to hot air? Would it rise if you took the cold air out from under it?" You can push air anywhere if you will make room for it to be pushed.

A Member: I would like to ask Mr. Adler if anything has been accomplished in the way of cooling great opera houses and rooms in hot weather?

Mr. Adler: Yes, to some extent; not on a very large scale, because it is very expensive. For instance, we have succeeded in the Auditorium in lowering the temperature three or four degrees and under favorable conditions even five degrees. We do it in this way. In the intake duct of the ventilating system there is a system of perforated pipes, and we have a very large cistern which we can fill with ice and salt and make a cold brine; pump the brine from this cistern into the shower in the intake duct of the ventilating system and by that means we cool the air. At the beginning we planned a system of mechanical refrigeration intending to use our heating pipes, the coils which in winter are used for circulating steam for heating, using them in the summer for circulating cold brine or ammonia for cooling. But we found the cost too great, and a great many difficulties in the way. But it is something that is practicable. It won't do to undertake to cool the air too much, because there are conditions under which you would be blowing a vapor into the room. When there is a high degree of moisture in the atmosphere, you would have trouble with the condensation of the air which you are cooling. You would get spray or vapor when you do not want it. Quite a number of years ago, during our first remodeling of McVicker's Theatre, it was proposed that the air should first be dried—be passed over a very hot surface and deprived of its moisture, and sent into the room. While the plan was very carefully worked out by its author, we could not think of adopting it, because of the enormous expense involved. Then, of course, air can be cooled, deprived of its moisture and then sent on its way to a room, but all those things involve complications that increase cost so much that they are impracticable. Probably the cooling of air by passing a shower of cold water through it is the nearest approach we will make toward any material cooling of the rooms.

Mr. Kerr: What is the practice here in regard to moistening the air, or is there any practice at all in regard to controlling the humidity?

Mr. Adler: Efforts have been made in that direction, but in my opinion if there is to be any control of humidity, it should be in the matter of removing moisture from the air, not adding moisture to it. The air in a large room where there are many people is never too dry, it is frequently too humid. The exhalations of the people in the room, breath and evaporation from the skin and all that, add so much to the moisture contained in the air, that no matter how dry it is when you send it in, it soon absorbs enough humidity to be entirely comfortable; in fact, one of the great advantages that would be derived from cooling the air to a very considerable extent before sending it to the room and then warming it again and then cooling it, is that much of the contained moisture would be precipitated and it would be sent into the room dry.

Mr. Westcott: Mr. Adler mentioned in regard to draining the boiler rooms where they were below the sewers of the city, that the sewage was pumped out; can he tell us the manner of that?

Mr. Adler: The water is gathered in cast iron tanks which are placed at such distance as may be desired, below sewer level. In that tank is a float which rises and falls with the rise and fall of the water, and is so adjusted that when it comes to the proper point it exerts a good deal of leverage. There is also somewhere about the building an air compressor and a tank for storage of compressed air. This is connected with a valve of proper construction in this gathering tank. Now, as the sewage water gathers in the tank and raises the float, at the proper moment when the float has arrived at the proper point, it opens simultaneously a valve for admission of compressed air and an escape pipe for water, by means of which the tank is connected with the sewer. The compressed air rushing into the tank blows the contained water out into the sewer, then when it has blown out enough water for the float to drop to the bottom, the valve closes and the process repeats itself, the air compressor continuing all the time to maintain pressure in the air storage tank. These ejectors are made large or small, depending upon the duty required of them, and they are generally in duplicate, so that if one gets out of order, the other one may be used. They do sometimes get out of order by foreign substances getting into the sewage system and being caught between the valve and the seat. I have known a case where in quick succession both ejectors in a certain building were stopped in their operation by foreign substances that had wedged themselves in between the valve and the seat, and the basement was flooded and a good deal of damage done. I have kept track for the past ten years of a large number of these ejectors and the one just mentioned is the only time where I have known of any flooding that occurred by

reason of an accident to one of them, and that was due to a combination of circumstances that is not at all apt to occur often.

Mr. Thomas Appleton: Is it the custom to bring the sewage proper into these low tanks; that is, if it would not be practicable to lead most of the sewage directly into the sewer without an ejector? If such were the practice here in Chicago, it would be only the basement sewage that would have to be ejected.

Mr. Adler: Yes, our practice here is this: We take all sewage that is above the first floor level into the street sewer direct generally by means of iron pipes. Then we have a system of surface drainage for the basement floor and also for the various plumbing fixtures that are in the basement, and the blow-off basins and boilers and so on, all those discharging into the ejector tank.

Mr. Appleton: I have been told of some buildings that do not buy water from the city supply. Where they have a low basement and where they have to keep the water level down in the basement, they procure sufficient seepage water from the ground to supply the boiler. This party told me there was a great deal of leakage from the pumps and the dripping water from the tanks and that would be gathered in a low tank with the seepage water from the ground, and proved to be good boiler water.

Mr. Adler: I have known that to have been done in a building of which I had charge. It is a matter of probably thirteen or fourteen years ago, where two very large walls or cisterns were built to receive the ground drainage water. Nothing else was turned into them, and they were used to supply water for the boilers. Now, the establishment has grown very much since that time, and I have not kept track of it and do not know whether they have continued to use these cisterns or not. It was at the Judd street shops of the Crane Company. I do not think it is done in any down-town building. I think I should have heard if it were done; still it is possible.

Mr. Appleton: There is another question I should like to ask as to the method of operating hydraulic elevators. I understand that originally it was the custom to pump water into a tank on the roof of the building and use that water for operating the elevators. Now, I understand, it is the custom to pump into a closed tank in the basement.

Mr. Adler: Yes, that is the custom, although there is also sometimes a closed tank in the attic. The only reason for doing that is that hydraulic elevators are run under much higher pressure now than they used to be. The limit of pressure in the open gravity tank is the height of the building and it does not give as much pressure as is necessary to operate the elevators. With this moderate pressure which is given by a gravity tank, the cylinder has to be large and occupy much space, and in order to economize space higher pressure is carried and compression used. In many respects a gravity tank would be preferable be-

cause it holds more water, thereby giving a larger reserve and a more uniform duty to the pump. The compression tank is liable to rapid fluctuations, because it holds but little water and but little air and the pumps have to follow the duty of the elevators too closely, particularly when there are but few elevators. Of course, when there are very many elevators it does not matter so much, because the duty becomes more nearly uniform.

Mr. Appleton: Is there any method of supplying air to those tanks?

Mr. Adler: Yes, there is generally an air compressor.

Mr. J. C. Bley: What are the advantages of carrying water of condensation and steam in the same direction in the system of steam heating referred to?

Mr. Adler: The main advantage in a one pipe system lies in the fact that it reduces the number of pipes and fittings required and the number of valves required. The chief reason for its use is its economy. It requires less pipe and while the pipe is somewhat larger, the number of fittings is much smaller and the number of connections is much smaller and the number of valves is about half. When a building is very high, the volume of descending water of condensation becomes considerable when its gets down to the lower portion of the pipe, particularly in very cold weather, and the ascending column of steam is met at the very outset by a descending body of water and it is cooled and some of the steam is condensed. While it is true it goes back to the boiler and the loss is not so very great, still it is a loss, and it is a greater loss than the loss consequent upon sending steam from the top of the building into the big pipe and then sending it down from there.

A member: I am personally interested in this question of humidity and there is one more question that I would like to ask in regard to that, and that is whether Mr. Adler has any data which would go to show how much the humidity is increased from the outside of a building in the course of a performance in an audience room?

Mr. Adler: I have none myself, but I think that they can be found in Mr. Billings' works on "Heating and Ventilation." I think there is a complete resume of observations and of data, to the very root of the matter.

XXXI

IMPROVED PORTLAND CEMENT,

By JOHN W. DICKINSON, Asso. Mem. W. S. E.

Read March 16, 1898.

The world does move, and while it would sound like stating an axiom to say that progress is making in all branches of industry, it is true that there are those who regard any improvement in Portland Cement as impossible, and even appear to deprecate the great advance which has been made by the American manufacturer. A clear understanding of "What is Portland Cement?" may assist us to note the wonderful progress made in the science in the last few years.

Portland cement is a product consisting of an intimate mixture of lime and clay-bearing materials burned to incinderation and ground to the fineness of flour. A perfect Portland Cement is a product consisting of an intimate mixture of lime and clay-bearing materials, with the elements in exact and perfect proportions and free from any deleterious or even adulterating substances ALL burned to a perfect clinker and the clinker ground to an absolute flour. Should the raw materials, even if of perfect composition, not be in a finely divided state or not intimately mixed, the chemical union of the different elements which should be accomplished by heat, is impossible, and the resulting product is simply calcined clay or calcined lime and not unground Portland Cement as it should be, and it would be immaterial how finely such so-called clinker was ground, it could never be Portland Cement.

Marked improvement has been made in the last few years in the preparation of the raw materials. Instead of going to the kilns in a coarse, unmixed condition and with the different elements varying from 3 to 5 per cent as was the former practice, and unfortunately is today in many mills, such precision is used in the best mills, that the raw materials are brought to a condition approaching impalpability, then thoroughly mixed and by the use of improved methods and competent supervision, the proportion of the chemical elements, viz: lime, silica and alumina, are so controlled that the variation never exceeds ½ of 1 per cent. Great advance has also been made in burning. Bear in mind that the lime and silica in a Portland Cement must all be chemically combined by heat, and to effect this combination, a great heat is necessary when the fluxing elements, alumina and iron are kept at their proper minimum, and no product of the kilns that has not been thoroughly cindered and consequently chemically combined should be used with the clinker making the finished cement, and

it is safe to state that owing to the improved process of burning adopted in the past few years, the proportion of underburnt material coming from the kilns has been reduced from 25 per cent to 30 per cent, to less than 5 per cent, and in some cases the product of the kilns is invariably perfect clinker. The higher the percentage of combined lime the stronger the cement, and owing to the improved methods employed both in preparation of raw material and in burning, the lime has been increased from about 55 per cent of the total to an average of 60 per cent, and in a few cases the entire process is so perfect that a percentage of 65 per cent of lime is successfully incorporated.

But it is probably in the matter of grinding that the greatest advance has been made. Before any great reform is possible it is necessary to realize first the NEED; second, the CURE, and as in the social and political world, so is it true in the physical, that the creating of a realizing sense of the NEED, is the greater part of the problem. Mr. Thomas Bevan, senior member of the firm of Knight, Bevan & Sturge, no doubt the most widely known name in the cement world, told me not long since that the coarse particles of clinker, or what would be the residue on a No. 50 sieve, were of equal value to the flour, and certainly the custom of the English and many of the continental factories, in shipping with their cement such a large proportion of coarse particles, confirms the belief that Mr. Bevan is on the side of the large majority. But, fortunately, this country while occupying in many ways the position of scholar, and we do not fail to appreciate our teacher, and to acknowledge the debt of the Portland Cement industry of this country owes to the English and German manufacturers, has by investigations made known the NEED, by determining that the residue on any known sieve is clinker and not cement.

Perfect clinker is sufficiently hard to scratch glass, and it is evident to anyone that will take two pieces of clinker, say the size of large diamonds, and wet the surfaces, that on putting them together no bond will result. Now, if we break up one of these pieces and attempt to cement together even the smaller particles, we find that these are no more cement than the larger pieces. By taking the residue on the 50—100 and 200 sieve, it will be found that the so-called cement represented by such residue is equally inert. Some investigators have reported slight strengths from the residue obtained by taking the intermediate of the 150 and 200 sieve, but I am positive that the strength thus obtained was wholly owing to the cement flour that adhered as dust to the coarse particles.

I have made many tests with the residue on the No. 200 sieve and in no case, where proper care was used to remove the impalpable powder, have I been able to get the least strength, so with the knowledge that no portion of a barrel of cement is active or possesses any cementing properties save that which has been

ground to an absolute flour, it was comparatively a short step to devising machinery and methods which produces 85 to 90 per cent of flour instead of only about 60 per cent, as was the product ten years ago. The progressive mills in this country are not satisfied with even this great advance, but are constantly striving to improve their quality, and effort will not be slackened until the contents of every barrel of cement is not only of the highest quality, but is so ground that there is the least possible amount of "*cement sand.*" As adobe was superceded by lime, lime by natural cement, natural cement by Portland, so have the coarse-ground, bicalcic-silicate Portlands of ten years ago been practically supplanted by the fine-ground tricalcic-silicate cements manufactured to-day, and there are forces and ideas at work that in my opinion, will in the future, produce a Portland Cement superior to the best now manufactured.

While opinions may differ as to the probable soundness and permanency of different cements as indicated by their varying characteristics, it is certainly true that other qualities being equal, the quicker a cement attains its maximum strength, the better it is for all purposes.

Cement work suffers more from careless and mischievous attacks during the first month than in any future twelve, so the quicker a cement sidewalk, floor, or foundation is hard and out of danger of attack from any source, the better, and it has been the aim of the American manufacturer to produce a cement that will get its maximum strength in the shortest possible time. How fully they have succeeded in this particular is seen by the following tables.

Cement is used only to bond other materials, so in the comparisons given I shall confine the figures to sand tests, as these alone show the relative values of different cements in the work which they are called upon to perform.

Not feeling at liberty in this paper to give the name of the American Cement tested in the accompanying comparisons, it will be called American X, while the foreign cements are indicated by brand.

R. L. HUMPHREY, INSPECTOR OF CEMENTS, PHILADELPHIA, PA.

	7 Days. 1 C.—3 S.	28 Days. 1 C.—3 S.
American X	230	350
Germania	180	235
Schifferdecker	145	160
Hanover	120	166
Alsen's	140	155

CHARLES E. GREEN, PROFESSOR ENGINEERING, UNIVERSITY OF MICHIGAN.

	7 Days. 1 C.—3 S.	28 Days. 1 C.—3 S.
American X	385	430

Star Stettin	271	372
Dyckerhoff	230	275
Germania	181	234

MAJOR MARSHALL, U. S. ENGINEER, CHICAGO.

	28 Days. 3 Parts Sand.
American X	316
Star Stettin	291
Alsen	278
Dyckerhoff	254
Lagerdorfer	231

CITY ENGINEER, CHICAGO.

	28 Days. 3 Parts Sand.
American X	378
Alsen	238
Dyckerhoff	274
Schifferdecker	242
Lagerdorfer	244
Stettin	268
Hemmoor	208

CHICAGO SANITARY DISTRICT.

	3 to 1. 7 Days.	3 to 1. 28 Days.
American X	326	423
Condor	158	222
Stettin (Gristower)	175 (2 to 1)	271 (2 to 1)
Lagerdorfer	139	186
Jossen	159	207
Oland	182	258

In the great lines of improvement indicated, viz.:

1st—Better preparation and more accurate mixing of the raw materials.

2nd—Uniform and complete incinderation.

3rd—By fine grinding.

This country has taken the foremost position, equalling at least in the first particular that of any other country, and in the 2nd and 3rd, easily leading the world.

American kilns are now being adopted by Dyckerhoff & Sons, of Germany, a name long the fetich of those worshiping at the shrine of prejudice, and in the method of grinding universally used ten years ago, the old-fashioned burr-stone has been so completely deposed by American grinding machinery or European adaptations, that it is no exaggeration to state that in the entire making of Portland Cement, this country is copying the manufacturers of the old world far less than they are following in the footsteps of the progressive manufacturers of America.

DISCUSSION.

A member: What are the chief qualities in the cement that give to it the quick setting properties spoken of?

Mr. Hennessy: It has been demonstrated by practical experience that the improved Portland cements of America get their maximum strength quicker than the Portlands made twenty to thirty years ago. There are several reasons for this quicker action, but it is no doubt principally owing to the finer grinding.

Mr. Adler: You have given us a number of test figures—none, however, extending beyond twenty-eight days. Have you any figures for a longer period?

Mr. Hennessy: I have none with me. Mr. Dickinson, no doubt, considered it unnecessary, as all the cements used in this list of tests are perfectly sound, and all continue to increase in strength. Climatic and other conditions cause all materials to fluctuate in ultimate strengths. The variation in strength of the natural stones, which of course must be considered to have obtained the maxim strength, vary materially in strength at different times, and, as would be expected, the same variation is shown in cement tests. This variation would be apparent in fifty years, or even a hundred.

Mr. Adler: Really, the two or three-year tests would be very interesting, because certainly cements which develop a great deal of strength in the first few months, and afterward sometimes, not until after a year or two begin to deteriorate, but deteriorate very rapidly. I believe that is the case where there is an excess of sulphur, or an excess of magnesia, and it would be very interesting to have long-time tests.

Mr. Hennessy: As I have said, I haven't them with me, but the relative strength obtains all the way through. Scientific knowledge has advanced sufficiently to determine whether cements are sound and stable, and whether there is any danger of any deterioration. The boiling test is the most accurate in this particular. Any cement that will remain intact in boiling water for eight or ten hours is permanent, and there is not the slightest possibility of any cement standing this test ever showing any but the fluctuations in test referred to previously.

Mr. Stephens: I would like to ask whether the specimen which shows maximum strength in a short time, that is would harden very quickly, whether such cement would in practice not be as good a cement as that which takes longer to harden?

Mr. Hennessy: I did not understand that Mr. Dickinson meant to say a cement that would set quickly was the best cement. What he said, was, "that would harden quickly." There is a difference between quick setting and quick hardening. The cement he had in mind does not get its initial set under two hours, and final set in over eight hours. That is slow enough for any work, giving ample time for all manipulation in the mixing and placing of the concrete, or mortar.

Mr. Stephens: Mr. Adler has undoubtedly had a great deal of experience in architectural engineering with cement. I would like to ask him about the valuable features in cement.

Mr. Adler: It is difficult at short notice, and without data, to express an opinion that has any great value.

I can see no reason why we should not make as good cements in the United States as have been made in Europe. As the superior efficiency and unwillingness to take things for granted of the German scientists produced in Germany, a cement that was infinitely superior to the English Portland cements, I cannot see any reason why the ingenuity of the American manufacturer should not produce a cement which is as good as German cement, and much that I have seen and heard of American cements, leads me to think that they may be at least on an equal footing with the foreign cements. There is one thing, perhaps, to be said about the use of cement in general, and that is our specifications, at least the specifications of architects relating to the use of Portland cement, are based upon the kind of cement that we used to get ten, fifteen or twenty years ago. We are satisfied with the concrete that was to be made, say, of one part cement, three of sand, three of crushed stone. Well, in fact with cement of high quality, of the better grades of German and American Portland cement, I believe we would be perfectly safe, if, in making mortar we were to use our sand in proportion of four or five to one and then our crushed stone in the proportion of four or five parts to one of mortar. In making concrete for architectural work, it is generally made on so small a scale that it hardly pays to get mixing machinery. If the sand and cement are mixed dry, if then the water is added and the cement mortar is very thoroughly mixed, turned over two or three times, if the mortar is then mixed with the crushed stone and turned over two or three times again, I am quite certain that the quantity of cement used need only be from one half down to perhaps one quarter as much as what archtects are in the habit of specifying. Our practice is based really upon the days when the Louisville cement, the various New York State cements were the best we knew, and when it was the practice to mix sand, stone and cement all together, turn them over helter skelter, get a mixture in which part of the stone was dry, and then again great lumps of sand and great lumps of cement, and mixture was not thorough, as by the by, came out some time ago in the report referring to bridge cables, where an engineer draws the conclusion that the contact of the limestone with the iron wire cable in the anchorages had produced oxidation. Well, it strikes me that if there is a concrete in which there are occasional chunks of limestone, that are entirely uncovered, that that is a concrete in which there are great spaces in which the binding material between the bits of stone is air, and where there is a channel at all times open for the passage of water into the interior of the anchorage and to the cable, consequently

then will be oxidation of the cable. But it strikes methat the great advantage we can derive from the present methods of manufacturing cements is the fact that we need not use as much of it; we can get away from the notion of the specifications derived from the days when we did not have any good cement. I refer to those English cements of which Mr. Dickinson speaks in his paper, where the residue on a fifty sieve, was considered plenty good enough to mix. Why, I suppose it was all right; it was just so much sand, that is all. It was not necessary to use as much sand to mix with this cement, because the sand was already in it. That seems to be the viitue of the cement which Thomas Bevan appears to have praised so highly; the sand was self contained, it was right there; there was no need of hauling it to the ground and mixing it.

My impression is that generally the American cements in architectual practice are supplementing the German cements just as German cements first supplemented the English.

There is a point with regard to the use of cement with architectural work about which there is a great deal of doubt, and as yet comparatively little positive knowledge, and that is the extent to which there may be ingredients in the cement that promote efflorescence on the face of brick and stone work laid with it. For many years it was assumed that the only cement in which it was safe to set brick or stone facing of a building, or any projections, was the La Farge cement, and it was specified for all important works throughout the United States. Then came the Meyer cement, the Puzzolan cement, which, I judge, must be a cement very much akin to that made by the Illinois Steel Co. I was persuaded to give that a trial under very peculiar circumstances. I built on top of the Auditorium tower a little stair housing, which was built of hollow, porous terra cotta tile, and coated on the outside with a very heavy coating of cement, and I was persuaded to use, in an experimental way, the Meyer cement, by my friend, Mr. Henry U. Frankel of Louisville, who was then agent of this cement. There was a coating, I should judge, about an inch thick on top of the tile. The exposure of that tower is very severe. We made the cornice also of cement; there was just enough variation of expansion and contraction between the hollow tile and cement to open a crack at the line of junction of the projection of the cornice with the hollow tile, and the water seeped into that and froze and thawed; and this state of affairs continued for several seasons until finally masses of cement were forced away from the tile, sufficiently so that I could put my hand into the open spaces. But with all the great volume of water that was gathered behind the cement coating no efflorescence was shown, demonstrating that there was a cement which, like the La Farge cement, could be trusted not to stain masonry. I understand from others that similar experiences have been had with Empire, with Alpha and with several other American cements, and I do not

know but what before long this bugaboo of efflorescence on the face of masonry arising from the brand of cement used may disappear, and I think it would be very well if as many cement users as possible were to observe this tendency, because the greater the number of brands of any material that can be used for any specific purpose the better it is all around; then the keener will be the competition, not only as to price but development of quality. It strikes me in the long run nothing tends more to retard the improvement of any particular output of the human mind and the human hand than monopoly of any particular article as to manufacture and sale exclusively. There is no effort made to improve, while if the field is open to many each one of those many will try to outvie the other, so it will be well if we learn of not only two or three brands of which it has been demonstrated that they will not produce efflorescence upon the face of masonry, but that there are many cements that can be depended upon for that.

Mr. Ball: I would ask of Mr. Adler what he thinks of the slag cement manufactured now?

Mr. Adler: I have not used it; I do not know—that is, I have not used any American slag, but I understand that this so-called German Puzzolan cement is also a slag cement; I think this must be said of slag cement, that it is, after all, a by-product and a comparatively unimportant by-product of factories which turn out millions of dollars worth of other product per year. It does not stand to reason that a big blast furnace will select its ores and the flux used in treating them and the various things which determine the makeup of the slag with reference to an output of slag for cement purposes; those things will be selected with reference to the output of pig iron, and with regard to the value of the pig iron when converted into an ingot and the value of that again in its relation to quality of finished product. My opinion with reference to slag cements would be that inasmuch as there are all sorts of ingredients in ores, fluxes and fuels, some of them deleterious to cements, that in the miscellaneous output of slag there might be a failure to exercise sufficient caution inobtaining just the right components in the slag itself. Mind, I am not sufficiently familiar with the process pursued at the mills in selecting the slag for the cement product to know but what that difficulty has been foreseen by the managers of the cement works in blast furnaces, and that careful chemical tests are made of the slag, perhaps of the ingredients of the blast before its smelting before they get the slag, and to determine the exact value of the slag for cement purposes. .I should think that engineers who use cement in very large quantities would find it well worth their while to watch the work in the establishments that make slag cements. We architects after all do not use much cement. A big building, even as big as the Auditorium, uses but a small quantity of cement, compared say with a great bridge or system of water works, or sewers, or anything of that kind. We are

not cement users, and we look to certain qualities in the cement that engineers do not look for.

The Chair: Is there any gentleman present from the Illinois Steel Co. that can answer the question suggested, not asked by Mr. Adler, as to the method of selection of slags ?

Mr. Morris Metcalf: I represent the Illinois Steel Co. I am not connected with the manufacturing end of the business, but I shall be glad to answer any questions I can.

The Chair: The suggestion which Mr. Adler's remarks would imply would be that, it being a by-product, the manufacture of Portland cement with the Illinois Steel Company, that it would be a catch as catch can affair in the selection of material. Now it may be assumed that that would make a good product, the same as Mr. Armour manufactures pork and also good pepsin, so that the question becomes an interesting one in that way, to know just exactly what the process might be as far as it can be given.

Mr. Metcalf: Something over a year ago I called on Mr. Adler in the interest of our cement, and during the conversation I mentioned a fact that he seemed to think rather strange at the time, namely, that the Illinois Steel Company practically ran one blast furnace to obtain a uniform slag for the manufacture of cements; and although that may seem on the face of it a rather absurd proposition, it is nevertheless true. I do not mean to imply that all steel companies would or could do that, but the cement department of the Illinois Steel Company is separate in every way from the Steel Company proper, and except for the fact that it is all under the same general management, it is managed and operated the same as if it were a separate company. Just as much attention and perhaps more is given to the regularity of the product as if it were a separate company.

I judge from Mr. Adler's remarks that he considers the fact of the cement being manufactured by a steel company and consequently becoming a by-product, rather detrimental to the interests of the material. Now it seems to me that this very fact is rather to its advantage. Cement has been manufactured in Europe from blast furnace slags for many years, though with indifferent success. This has been partly due to the fact that the slags of Europe are of themselves not at all uniform in composition; it is also due to the fact that the slag producers of Europe are seldom the cement manufacturers, and as the former consider the latter of secondary importance they make little effort to produce uniform slag and consequently uniform cement. The result is an article not to be depended upon, though at times of striking excellence.

With us, however, the case is very different. Our ores are the purest and most regular in the world; moreover, before the material is used it is subjected to the most careful chemical analysis and all material not of the correct composition is absolutely dis-

carded. It seems to me that a more uniform cement can be obtained where it is a by-product of a slag producing company than if it were made by a separate and disinterested company.

I wish to repeat that it is acually a fact that the company operates one blast furnace at its North Works, the ores for which are selected with a view to making a slag of regular composition and suitable for the manufacture of cement. You will appreciate that this can readily be done without affecting the quality of the iron or the economical operation of the furnace.

As a matter of fact, the iron of course is the main product, but it is a part of the necessary composition of the slag to be satisfactory to the iron, and it may also make a good cement, and that is also regulated by the fact that the chemical work is carried on in connection with the making of the cement in the same way, and for the same reason that the chemist watches the composition of the iron. So the mannfacture of cement is watched; the tests are carried on in exactly the same style and for exactly the same purpose. The fact that the slag is a by-product, is no reason why it should be condemned. You might say that rock or marl, which the other cements are made from, are by-products in the making of mountains and of natural scenery.

Mr. Kerr: Some years ago I saw a bricklayer, who had just eaten his lunch, walk up to a pile of cement that had begun to "freeze" a little while he had been eating his lunch, and he poured some water on that and began to mix it with his trowel to use it. I asked him if that did not weaken the cement; he said "no, it makes it better, this re-working it." I did not have any particular faith in what he said at that time, but I have not seen anything bearing on that point, and I have not seen any experiments. I would like to ask of Mr. Hennessy, who speaks of the initial time of setting, three and one-half hours, if he knows what the effect would be on that cement, if, after a half hour after setting had commenced, it was re-worked, what effect it would have on the time of setting after that, or upon the maximum strength, etc?

Mr. Hennessy: I am of the opinion that when a cement gets its initial set, if one should undertake to work it over again, it would do what is called, break it down, and it would destroy the value of the cement. I do not believe that any cement that had commenced taking its initial set and a little bit later, would be of any value if they take it and trowel it over again. Before it got its initial set, however, it would not hurt it in any particular. That is as much as I know about it, and we have made experiments in that line. We tried to re-work it after it had its initial setting, and it would not work at all.

The Chair: There is one question you raised there that I would like to inquire about. You say that it was frozen and he re-worked it—that he re-worked it to keep it from freezing.

Mr. Kerr: I used the word "freeze" there in the sense of setting, that is what they call it. It was not freezing weather.

The Chair: Freezing sometimes will suspend the operation of setting, and cement will sometimes preserve its elasticity after it is thawed.

Mr. Adler: Provided it is not meddled with.

Mr. Kerr: In this particular case I am satisfied that this cement, which I believe was the Louisville cement, had actually set at that time. I do not know of course what difference there may have been in the ultimate strength.

The Chair: I had an experience some years ago with natural cement, in a case where it was used simply for the weight which the cement furnished; that it should have enough elasticity to stay together and form an anchor. The mass was something like 10x12 feet in a vertical direction, and about sixty feet in length, and was the anchor for a shear leg crane which was erected at the ship yards at South Chicago, but its whole office was simply to lay on the ground and hold itself down, so that the question did not come up of the hardness of the product or its ability to bear weight, no more than that the anchorage should not pull through it, as the weights coming on it were very heavy, something like 200 tons. Conditions were such that we were obliged to get the crane in operation to place some boilers in a ship that was being built at the yards, and we had to push the work when the temperature was from zero to fifteen degrees below zero. Well, we used ordinary precautions and mixed it with hot water and kept our sand as warm as we could considering the weather, and the stone in the same way, and dumped it through a spout into the hole, and at the end we filled up the hole with water, it would freeze over, when we would take of the covering five or six inches of ice had to be taken off, and we would go on with the work. That was left in that shape till next spring. I do not recommend this as a mode of construction with concrete, but at the same time it shows the result. Along in June I was called to the yard one day, was told that the foundation was all falling down, the anchorage of the shear legs was all falling to pieces. I went down there and found that the ground was all caving in around the crane, and by digging down a little way we found snow and ice where it had been dumped outside of the sheeting, and covered over. It was shoveled out and we heard no more of it for about six months; then we undertook to channel across that block of concrete to get another bearing to run a pipe through, and we had to do it with a cold chisel all the way through. That was simply a single experience in the way of misuse of cement, if you please.

Mr. Windett: At the South works of the Illinois Steel Co. there were two retaining walls put in about sixty-six feet long by two feet wide, exposed to the atmosphere about four feet. These were put in about a year ago, and they passed through the winter exposed to the weather, and at present I have not noticed any cracks on the face. A year ago last February, when the weather

for a week or ten days was down around zero, running somewhat below, we put up an addition to the rail mill at the southern part of the building, which foundation carries traveling cranes of twenty-five ton capacity in daily use. Those foundations were put in with slag cement, and broken slag for stone, and we have had no trouble whatever from the settling or cracking or deterioration of the foundation in any way at all.

XXXII

FIRE-PROOF CONSTRUCTION AND PREVENTION OF CORROSION.

By GEN. WILLIAM SOOY SMITH, Mem. W. S. E.

Read April 6, 1898.

The use of combustible materials in buildings of all kinds endangers life and property to an extent realized only when we are startled into thinking by some great conflagration or appalling destruction of life by fire.

When a dozen or two of people, unable to escape from a burning building, or two or three firemen nobly battling with the flames, are burned to death, we read a notice of the deplorable event in our daily paper and exclaim, "It is awful," or "It's too bad," and pass on to the latest news or to spicy society gossip and think no more of occurrences which from their very frequency cease to make deep and lasting impressions. But if the great aggregate of destruction of life and property by fire during a single year could be carefully and accurately made up, the world would stand aghast at the horrible revelation.

While such wonderful progress has been made during the latter half of the nineteenth century in the development and applications of physical science, is it not passing strange that so little has been done to mitigate this stupendous evil?

The term "fire-proof" is only relative, for there is scarcely anything that will resist the highest known temperatures if applied for a few hours only. And the best and cheapest materials used in buildings do not belong to this class of very refractory substances.

The evil can be mitigated or prevented by the best possible protection that can be given to these by fire-proofing, and by preventing the very high temperatures that might otherwise be developed by fires by admitting only the very smallest quantities of more combustible materials, both in the construction of the buildings themselves and in their contents.

Even in the construction of small houses a cheap wooden frame can be erected and covered, both inside and out, roof and all, with a first-class fire-proof plaster that will stand exposure to weather and make dwellings that will be cheap, fire-proof, warm in winter and cool in summer, needing no painting, and which will be practically as durable as brick or stone houses.

Larger buildings may be constructed in like manner, and even brick and stone structures may be so plastered and made fire-proof, and be otherwise greatly improved.

The subject of buildings is of vital interest to all mankind. Our convenience, comfort, health and safety depend largely upon the character of our dwellings and of the buildings in which our labor is done and our business transacted. It is especially requisite that the materials employed and the modes of construction of buildings shall be such as to make them strong, durable, safe and economical. They should also be as nearly as possible proof against destruction by fire, or by fire and water combined, as they are generally exposed to the joint action of the two in cases of conflagration.

The "skeleton construction" now so common in large cities for tall buildings is about as faulty and objectionable as it can be when exposed to this combined action. The expansion of the steel the buildings contain is at the rate of a tenth of an inch per foot for a change in temperature of one thousand degrees (red heat). The other materials, stone, brick, terra cotta, etc., each has its own rate of expansion differing from each other and from that of steel. They all differ also in their conductivity of heat. If these materials and steel are raised in temperature equally throughout their whole length, the increase in length will differ in each material, and taking the conditions as they occur in almost all burnings of buildings, the steel will, on this account, be heated much more quickly, and throughout a much greater part of its length, than any of the other materials present. The differences in the total dimensions of the several parts of the building resulting from these causes is so great as to bring about a destructive war between them. This is not mere theory, although it is correct. Close observation of the effects of fire on buildings discloses the same facts.

When a fire is in progress in a building and its parts heated to a high temperature, the fire engines throw powerful streams of cold water on the heated materials, and most of those now commonly employed fly to pieces under this joint action of fire and water. So says Chief Swenie, of the Chicago fire department, and all who have become familiar with the effects of fire and water on building material. This is especially true of the light integument of terra cotta built around the steel columns of a skeleton building.

A. W. Smith, an expert tester, having served the writer for the last two years making tests of various so-called fire-proofing materials, makes the following report:

CHICAGO, April 5, 1898.

"During the time we were engaged in the effort to discover a perfect fire-proofing, I think that nearly, if not quite, every kind used here in the construction of buildings was thoroughly tested and none was perfect; some of them endured fire alone, some endured water, but all save one yielded to fire and water. The clay tile not only transmitted heat too readily, but also when

heated to a red heat and subjected to a jet of cold water went to pieces. I found one porous clay tile which withstood the test of red heat and cold water without yielding or cracking. It was a hollow porous tile made by Lehmann & Kohlsaat in the northwestern part of this city. The tile was about two inches thick and eight inches square. It took twenty-five minutes to heat this tile over a very hot flame so that the hand could not be borne on the top. I plastered a tile of this kind on both sides with a three-eighths inch coat of asbestic plaster and the transmission of heat was thereby so greatly retarded that when placed in the same heat for one and one-half hours the bare hand could be borne for a brief time without pain on top of the tile.

"I found one of the compounded fire-proof tile, made in this city, to be the best non-conductor of heat I have ever seen. But it will not endure fire alone or fire and water, and is in my judgment lacking in strength for many of the purposes of fire-proofing. It will literally burn up slowly, though it will not blaze.

"As to these compounded kinds of fire-proofing, I believe it to be true that several of them will burn slowly. Some of them will soften nearly to the consistency of pulp even in cold water, and not one of them will endure the application of cold water when they are brought to a red heat.

"Our best results were obtained by plastering the Lehmann & Kohlsaat tile, a tile composed chiefly of asbestic.

"The asbestic fire-proofing, when used in connection with steel or expanded metal lath, works admirably for the protection of all the members of steel, iron or mill construction, while it is beyond all question unequaled as a wall plaster. The last statement has been frequently demonstrated in eastern cities and here in Chicago. The plaster is strong, practically indestructible by fire, and as a non-conductor of heat is simply wonderful.

"(Signed) A. W. SMITH."

Iron and steel being the strongest materials used in the construction of buildings, and in proportion to the service to be performed one of the cheapest, have deservedly come to the front rapidly as a building material, particularly in the United States, for the very high buildings that have been erected in the business districts of large cities in which the high prices of lots make it advisable to secure the greatest rentable space practicable on a given area.

The experience previously gained in the construction of iron and steel bridges throughout the world prepared the way for the use of these metals in buildings, and to some extent developed correct methods of proportioning and connecting their parts. But it seems remarkable, in view of this experience, that such radical defects still creep into the details of iron and steel framing in buildings—such as the flimsy lug and bracket connection of beams and girders with the columns, the eccentricity of loads

on the columns, and the want of provision for expansion and contraction of the parts of the skeleton of a building. These defects are easily remedied.

And now supposing that all the metal parts of a building are properly shaped and connected, and all the loads and strains which the skeleton frame is to sustain are amply provided for, two great dangers threatening the safety and durability of the building still remain, viz., the weakening and destruction of the metal members by corrosion or by heat. These dangers are actual and obvious. But the precise rates of weakening by heat, and destruction by corrosion under different circumstances are not as accurately known as they should be.

A column of iron or steel, such as those now commonly used in high buildings, would hold little more than its own weight when red hot; and it is well known that there is a dangerous weakening effect of heat at much lower temperatures.

Tests made at Watertown, Mass., in 1890, by Mr. Jas. E. Howard, for the author, led to the following conclusions, viz.:

"The modulus of elasticity of both iron and steel decreased with an increase in temperature, the change being more marked with mild steels.

"The elastic limit, like the modulus of elasticity, decreases with increased temperature, the rate of change being affected somewhat by the amount of carbon in the steel. With an increase in temperature there is a decrease in tensile strength; the latter in case of mild steels reaches a minimum at about 200 degrees Fahrenheit. With a still further increase in temperature, there is also an increase in tensile strength, but at about 460 degrees Fahrenheit the tensile strength reaches a maximum. As the temperature rises above this point the tenacity diminishes rapidly."

The following table compiled from experiments made by R. Luehmann, Hamburg, 1888, is very instructive, showing that the breaking load of a wrought column per square inch of cross section when red hot is only one-half as great as when the column is cold (normal temperature).

From this it must be apparent that the usual method of giving to columns, beams and girders, certain loads and proportions such as to secure ample strength with a proper factor of safety while the metal is at ordinary atmospheric temperatures, is altogether insufficient to ensure safety in case of exposure to the high heat that may attack it during a conflagration. And here let it be remembered that the metal while heated loses much of its strength to resist tension and compression, and also loses in greaterdegree its resistance to lateral flexure, and so the entire skeleton of a building may be deprived of a stiffness necessary to its stability.

It also happens that while the columns, beams and girders are weakened, they are also expanded by heat and unequally, as the degree of heat to which the different members are exposed

TABLE I.—TESTS OF IRON COLUMNS.

No.	Kind.	Temperature.	Length.	Area of Section.	Load at Rupture. Total.	Load at Rupture. Per Sq. In.	
				Sq. In.	Lbs.	Lbs.	
1	Cast	Cold	3′ 3-3/8″	10.4	430,452	41,390	Opening through column .2″ eccentric. Diams. of Cyl. 5.9″ and 4.72″.
4	Cast	Hot	6′ 6 3/4″	10.4	218,000	20,961	" " " 5.9″ and 4.72″.
2	Cast	Hot	3′ 3 3/8″	10.4	165,000	15,865	" " " 5.9″ and 4.72″.
6	Cast	Hot	6′ 6 3/4″	10.4	260,000	25,000	Cyl. filled with P. Cement mortar 1 to 1.
7	Cast	Hot	6′ 6 3/4″	10.4	218,600	21,019	* " " " " " " 1 to 3.
8	Cast	Hot	6′ 6 3/4″	10.4	282,000	27,115	Coated with P. Cement mortar .236″ thick.
9	Cast	Hot	6′ 6-3/4″	10.4	231,000	22,211	No filling or coating.
14	Cast	Hot	6′ 6 3/4″	10.4	324,500	31,202	Flat ends. Did not break.
15	Cast	Hot	6′ 6-3/4″	10.4	231,200	22,231	
11	Wrought	Cold	6′ 6-3/4″	10.4	227,000	21,827	
3	Wrought	Hot	3′ 3 3/8″	10.4	133,760	12,861	
5	Wrought	Hot	6′ 6 3/4″	10.4	106,000	10,192	
10	Wrought	Hot	6′ 6 3/4″	10.4	218,600	21,019	Coated with P. Cement mortar .236″ thick.
12	Riveted	Hot	6′ 6 3/4″	9.8	301,000	30,714	Covered with wood and sheet iron.
16	Riveted	Hot	6′ 6 3/4″	9.8	172,000	17,551	Flat ends. Not covered.
13	Cast	Hot	6′ 6 3/4″	10.4	370,000	35,577	Flat ends. Fluted column with capital.

With the exceptions noted, all columns had round-end bearings.

*2″ wrought iron pipe running through column; pipe filled with mortar.

varies. The unequal expansions of the horizontal beams and girders push the columns out of vertical into buckling positions, rendering almost certain a collapse of the whole structure.

This has already occurred in many instances, and is likely to occur whenever fire attacks a skeleton building in which the metal parts are not absolutely protected by proper fire-proofing.

It also frequently occurs that the horizontal expansions of the beams and girders crack and shove out the walls, against which their ends abut.

Many buildings having skeletons of iron and steel imperfectly protected by so-called fire-proofing have failed when heated by fire either in these buildings themselves, or in some instances from the burning of an adjacent building even at a considerable distance away, notably in the case of the Manhattan Savings Bank building, corner of Bleecker street and Broadway, New York, which was ignited by the burning of another building forty feet away and practically destroyed, and the three steel skeleton (so-called) fire-proof buildings ruined by fire in Pittsburg, Pa., on May 3, 1897. The story of this fire was summed up in a few lines as follows: (Engineering News.)

"A fire starts in an old type of brick and wood low combustion building filled with highly inflammable material, and before its progress can be checked, it sweeps over an area of nearly two city squares, destroying property to the amount of $3,000,000. Within this area, besides the first mentioned buildings, there were three modern fire-proofed steel skeleton buildings and half a dozen small shops and dwellings of ordinary brick and wood construction. When the flames had completed their work there remained of two of the fire-proof structures only the outer walls and shattered floor arches held together by the steel frame; the third fire-proof building had five of its light floors swept nearly clean of their contents, and their dividing walls and partitions injured beyond repair and the brick and wood shops and dwellings were simply heaps of masonry."

This brief description clearly established the fact that the three "fire-proofed steel skeleton buildings" were not fire-proof, and indeed it turned out that in one of these 50 per cent of the columns were found, after the fire, stripped of their covering.

Many other instances may be cited, all teaching the same lesson, viz., that while steel at ordinary atmospheric temperatures is the cheapest, strongest and best building material known, it can only be considered safe and durable when thoroughly protected from high heat and corrosion. The rate of corrosion of iron and steel varies greatly under different circumstances. In pure water, containing no free air, with an airtight covering of paint or imbedded in quicklime, it scarcely corrodes at all, but when in the open air, particularly when alternately wet and dry, it rusts quite rapidly, and when exposed to steam and sulphurous fumes, it is eaten away by corrosion at the rate of one-eighteenth of an inch

per annum, as was the case in the floor system of the viaduct in Milwaukee avenue, Chicago, under which locomotives were passing frequently; and corrosion at the same rate occurred in a portion of the western approach of the Eads bridge at St. Louis, where the same circumstances exist.

As the metal in a steel column is usually not more than one-half inch thick, corrosion at the above rate would make a steel building unsafe in less than twenty years.

In an iron or steel skeleton building the columns starting at the basement floor, or at the floor at street level, extend to the top of the building. They are hollow and painted only on the outside, and this with paint that is so perishable that it will afford no protection from corrosion after the first five or ten years. The girders are nearly as much exposed as the columns, while the beams are generally bare on the top and bottom surfaces of the flanges, and sometimes over a considerable part of the webs.

Wherever the surfaces inside or outside are left uncovered they are exposed to corrosion that will be more or less rapid according to the temperature and hygrometic conditions of the air surrounding them. And in many instances, particularly in factories, there are destructive elements in the atmosphere, such as sulphur and chlorine, which may cause rapid wasting away of the metal, and which are the more dangerous, as they are apt to escape notice.

A steel or iron skeleton building can be made safe and durable only by thorough knowledge of the nature of these metals and careful provision against the dangers that threaten it under all the conditions of their use.

Supposing that the structural details are correct, care must next be taken to prevent corrosion. This may be done by covering all metallic surfaces, both inside and outside, with an indestructible coating of a material that will absolutely prevent corrosion.

This having been done, all the metal parts must be enclosed in a fire-proof and fire-proofiing material that will not only resist the heat of a conflagration, but so shield the metal from attack by heat as to prevent any considerable changes of its temperature. And this may be best and most certainly accomplished by having an eye to the fire-proofing of each individual member.

Slow combustion of buildings can be secured by carefully whitewashing the inside and outside with fire-proof material laid on with a brush. And fire departments claim that they can extinguish almost any fire if it is only prevented from spreading too much until they can bring their engines into play.

It is of the utmost advantage to protect each building from the danger of ignition in the case of the burning of its neighbers, and this can be at least measurably done by the whitewashing suggested, and by putting fire-proof shutters on all windows and openings of every kind. Where there is an open court in a building some sort of fire-proof covering should be put upon all parts

of such court, and the same protection should be given to stairways and elevator shafts.

These dangers and the necessity of protection from them are ably presented in a paper on "Fire-Proof Construction," written by Mr. Purdy, civil engineer, and published in the proceedings of the American Society of Civil Engineers, September, 1897.

The essential characteristics of a fire-proofing material for buildings are:

1st. It must itself be incombustible.

2d. It must be as nearly as possible a non-conductor of heat.

3d. It must be strong and durable.

While there are very many so called fire-proofing materials in use for which these qualities are claimed, up to a very recent period there was not one of them that was a good non-conductor of heat, that would stand heating to redness, and being plunged into cold water while red hot, without flying to pieces.

Within a few months, after years of careful experimenting, and testing the material, "asbestic" was discovered, which possesses all the requisites above enumerated, as proven by severe tests on a large scale at Montreal, New York, Washington and Chicago.

The requirements of a building are that it shall be strong enough to carry all its loads and resist wind pressure and all other strains to which it may be subjected as a whole or in any of its parts. That it shall be as nearly as possible fire and weather proof, and that it shall be durable and not unreasonably costly.

Supposing that steel is used for the framework of the structure as being preferable to any other for the frames of large buildings, and that proper shapes and sizes of all parts of such frames have been carefully and correctly determined, and the disposition and connections of these parts have been properly made, it only remains to cover the skeleton of a building inside and outside, roof included, with an integument that shall be fireproof, strong and durable, and, if possible, light, tough and elastic and a good non-conductor of heat and impervious to air or water. Such covering can be made of fire-proof plaster of any necessary or desirable thickness, and suitable cornices and mouldings can be worked out of the same material.

As soon as the skeleton is erected every part of it should be covered with a thick coat of the fire-proof material laid on with a brush.

The metal lathing should then be put on, strengthened where necessary by angle or tie iron covering all parts of the frame and leaving an air space between the lathing and every part of the frame.

A form of metal lath of trough shape and projecting ledges on the plastering side permitting the plaster to go through an open key-hole back to a double retainer on each side of the trough, and with a practically continuous key or clinch, has been brought but by Mr. G. A. Turnbull, which, secured to the skeleton frame

of a building, will receive the plaster and hold it admirably while adding also greatly to the strength and stiffness of the frame. Strong floors and ceilings can be made by the use of this same form of lath and trough flooring.

The great weight of tile, brick and stone now used would thus be dispensed with and the much lighter construction described substituted. A very great saving of weight in the frame itself would be saved and the cost of the necessary foundations of the buildings be greatly reduced.

There would be so many other important advantages realized that we need not describe them here.

Enough has been said to invite the careful and unprejudiced study and criticism of engineers and architects, and out of this kind of investigation there may come a new system of building that may be the ideal one of the future.

XXXIII

FIRE-PROOFING OF WAREHOUSES.

By Mr. Frank B. Abbott.

Read April 6, 1898.

Our modern steel skeleton building marks an era in the history of architecture. In pre-historic times, in the Druidical epoch, if I may be permitted the term, the architect practicing without a license but still building wisely and well according to his light, and with the primitive material then available, set up on end, at regular intervals, rough hewn or nature shaped posts of stone. Upon these posts and spanning the intervening spaces he laid other pieces of stone; upon these horizontal pieces he laid wooden poles, covering the whole with leaves and grass, and right here the simple principles underlying all architectural form were born—the column and the lintel. Through all the ages that have intervened we have not improved much upon these principles. We have varied them, it is true, we have used various materials from which to construct these two primary members, we have embellished them, we have placed a basket with Acanthus leaves growing around it on top of the column, we have inscribed the names of dead heroes on the lintels, but the column is a column still and the lintel is still a lintel, and while some of our profession seem never to have heard the old adage, "Ornament construction, but do not construct ornament," and in violation of the adage have at times almost concealed the true functions of column and lintel, still the two supporting members remain and will remain until the end of time, or until nature rearranges her laws

These two members are about all there is in a building aside from the finish and embellishment, for the beams and girders are but ramifications of the lintel, and struts and pilasters only undeveloped columns.

I repeat that the steel skeleton building marks an architectural epoch. The Romans marked an epoch when they introduced the arch and religion marked another when it drew the arch together at the top pointing up to heaven, but the use of steel has brought us back to earth, and with this new material we are starting again where the Druids did thousands of years ago. But we have the advantage of them, for a good many mistakes have been made in building construction since they set up the first column, and we are profiting by these mistakes. In those and in later times, the column could not be high without being pretty thick, and the lintel could not be long without being pretty deep, so the spaces between the columns were short, and

the Romans tried a curved lintel made of Voussoirs in order to overcome the difficulty.

But today we are back to first principles and are working out the same problems, so far as structural members are concerned, as were the Druids and the Greeks, but with the advantage of all that learning, science and experience has evolved in the intervening years; that is to say, the legs and ribs and backbone of our buildings are of steel today instead of stone or wood, because steel is stronger, and columns and lintels made of it are less limited in height and length, because carrying equal loads it is smaller in sections, because it can be readily worked into a thousand forms and when put together in a building becomes as one piece, a unit, without joints or seams, reaching higher toward heaven than the pointed arches of the old cathedrals.

You then naturally remark, "Steel must be the best building material," and I reply, "It is the best if properly handled." "But," you say, "why does not every one use it in building operations?" Every one will use it; it is only a question of time. It is only a question of time when all buildings will be built of this material, residences, churches, warehouses.

Our navy today is all steel, from keel to turret, and our residences and business buildings will be all steel in the near future, and not fire-traps for the destruction of life and property.

The word "fire" reminds me that I was not expected to talk about architecture, or about steel construction of buildings, but about fire-proofing. The preceding remarks are intended as a preface to the subject-matter. It is needless to say that fire-proofing wooden construction is a paradox and a delusion, and fire-proofing stone absurd; therefore, it is assumed that when we speak of fire-proofing, we mean protecting steel and iron from the attacks of fire, for while steel is the best building material, it has two enemies, and in the light of recent discoveries it is difficult to say which is the greater.

Investigations recently made by the American Society of Mechanical Engineers, as to the condition of the steel in the frames of modern office buildings, reports of which investigations were published in Volumes XV and XVI of their transactions, show that in many instances the metal had been seriously attacked by corrosion, and there is small room for doubt that were the tile and terra cotta coverings removed from the steel skeletons of our great modern buildings, we should find that rust had set up its dangerous work in many places. Putting a covering over the metal and calling this covering fire-proofing does not insure the metal against corrosion, and sometimes, unfortunately, not against fire. Fire and corrosion, then, are the enemies of steel—the one bold, flagrant, irresistible, the other unseen, silent, insidious. Now, if we can keep these two enemies at bay, we have a perfect and enduring building.

To prevent corrosion of the metal is not a difficult matter, as it is only necessary to keep out oxygen and moisture. But I wish to remark, in passing, that painting the metal is but a short-lived protection, as wherever air currents occur along the steel members—as is frequently the case where hollow air spaces are left between the fire-proof covering and the steel, particularly where these air currents originate in basements or areas where there is moisture and warmth combined—the painting will protect the metal but a few months.

Now, a fire-proofing material, of whatever kind it may be, to properly perform its work must entirely cover the metal on every side, wholly envelope it, and be of such nature and thickness as will prevent the transmission of heat. This being so, it follows that, if this fire-proofing material has the further quality of being impervious to air or moisture, we can then successfully resist the two enemies of steel in buildings with one material.

So far, history shows that iron embedded in cement and concrete is preserved from rust, as for example, iron cramps laid in cement joints, and used to hold together the lintels of the Parthenon have been found intact, and anchors imbedded in the concrete of the walls of the Coliseum of Rome when brought to light are as bright and untarnished as when new, and coming down to our own times, we bury the steel beams of foundations in concrete to prevent the action of rust, and the inside of the bottoms of the steel ships of our navy are protected from rust by a covering of Portland cement.

Therefore, if our fire-proofing material is concrete, and wholly protects the metal from fire, it will preserve it from rust. The proposition advanced, then, is to surround every column, beam, strut or other structural member with concrete, and not only surround the metal, but envelope it on every side, leaving no air spaces externally or internally.

What kind of concrete is best for the purpose? My experience shows that the best concrete is, first, one that is a fire resistant; second, one that will not expand under the action of heat; third, one that is light; fourth, one that is sufficiently strong for the purpose; fifth, one that is high in lime. There are a number of substances which, mixed with mortar of cement, will make concrete which conforms in the main requirements to that above described, but they are more or less dense and therefore heavy. In the ten-story manufacturing building, 171-173 Canal street, Chicago, the concrete fire and rust proofing is made of soft coal cinders mixed with Louisville cement, in the proportion of four of cinders to one of cement. These floors weigh about thirty-five pounds per square foot.

The lime of commerce is one of the best fire resistants known, and concrete for fire-proofing purposes is best that contains the greatest proportion of this ingredient consistent with strength. In the Druecker warehouse, now being built, the columns will be

protected by concrete made of one part natural rock cement, one part lime putty and four parts cinders. This concrete material will be rammed into the internal cavities, as well as entirely surround the columns, the nearest approach of the metal to the air being four inches when the column is finished. After the concrete is set it will be covered by a metal lath, on which will be spread a thick coat of dense hard mortar. Wooden cylinders, four feet long and made of two-inch staves, hinged so as to open in the direction of their length, will be set around the columns and the concrete rammed into place from the top. As soon as one four-foot section is concreted the second section is constructed on top of the first, and this process continued to the top of the column before floors are put in, thus securing a continuous envelope to the column, without joint from basement to roof. The metal lath is used to provide a better key for the mortar finish and to protect the concrete from possible injury under high temperatures.

The steel will have no painting whatever, but will be cleaned of mill scale and other foreign substances at the building, before concreting, as nothing should be put upon the steel to prevent the perfect adhesion of the cement to the metal, as the cement in the concrete settles about the metal and deposits upon its surface a coating while the concrete is being rammed into place. The external columns will be covered with hollow bricks, and the spaces inside this outside covering filled with concrete material, the same as other columns.

In any building during a fire the point most fiercely assailed by the heat and flames is the floor construction directly above the fire, and there has been plenty of evidence to support the statement that if the floor construction of any building is impregnable to fire which may occur or originate in any story, then the damage from fire in such a building will be slight so far as the building itself is concerned. The fierce heat generated in burning buildings is caused by the floors burning away and thereby creating a draught through several stories.

To make a building fire-proof we must so construct the floors that fire cannot get through them, and in this connection it is perhaps well to say that there should be no openings of any kind whatever through the floors in buildings used for warehouse purposes, and all stairs and elevators should be enclosed in solid brick shafts.

In the Druecker warehouse the floors will be made wholly of cinder concrete put in as arches between the beams, and so constructed as to give 4 inches of concrete on the lower flanges and 3 inches on the upper, and the underside of all floor construction, meaning the ceilings, will be covered as are the columns with metal lath and plastered with hard mortar. The accompanying details show the method of application.

This concrete floor construction serves also another useful pur-

pose, for when set it makes each floor a monolithic mass, a unit, which has great value as a stiffener to the frame work of the building.

There has been too much thought devoted to making floor construction strong and not enough to making it proof against fire and water. The architectural and engineering journals of the day as well as the hand books on fire-proofing teem with the record of tests and photographic reproductions of the great carrying capacity of the various kinds of fire-proof floors, but instances of fire-proof floors failing because of heavy loading are so rare as to have little interest, while the records of the insurance companies show heavy losses because of the failure of so called fire-proof columns and floor beams.

In the recent Pittsburg fire one of the burned buildings was stripped of 50 per cent of the tile fire-proofing by the action of heat and water.

In a private test made on several pieces of cinder concrete in the furnace under a boiler, the test lasting about 40 minutes, the temperature was raised to the fusing point of wrought iron without showing any serious injury to the concrete blocks. These concrete blocks were 5″x8″x10″, and various grades of cement were used, the concrete being made of one part cement, one part lime, four parts cinders.

Second only to making the construction of buildings impenetrable to fire is the necessity of confining the fire to the floor where it originates, and if the stairs and elevators are in a fire-proof enclosure, then the fire can be communicated to other floors only through the windows of the building, and in this connection a new material will probably become of considerable assistance—namely, wire glass windows in heavy metal frames. Recent experiments show that such windows are splendid fire resisters and will stand heavy pressure.

The relation that fire-proofing bears to insurance is an intimate one, and the insurance companies, always close observers of conditions during a fire, and whose discernment of the value of fire-proof materials is constantly being sharpened by destructive fires, are perhaps as good judges of the comparative values of protective coverings to steel as any business class that is interested in building matters. I presume it would not be assuming too much to say that they are the best judges. When a man or association of men undertake to insure property losses brought about by fires and by the firemen in their efforts to subdue fires, which efforts are frequently productive of as much loss as the fires themselves, it is but natural that these men should be constantly on the lookout for any valuable thing which will assist in keeping down the aggregate loss on a building and on its contents, in the event of a fire.

Comparisons are odious but facts are stubborn things. In the Felix & Marston warehouse, Chicago, built about four years ago,

which building was fire-proofed with cinder concrete, in general manner as shown by details of construction exhibited here, the rate of insurance made by the insurance companies on the building was 45 cents, and that too on a building filled from cellar to roof with a very inflammable material, namely, wooden and woolen ware. This is the lowest rate in Chicago on a warehouse stored with this nature of stocks. The warehouse occupied by Felix & Marston before this new warehouse was built was a mill-constructed building of the approved type, namely: Posts and girders of large section; 4-inch floors with asbestos linings, etc., and was considered regular mill construction by the underwriters. It was five stories and basement in height and had heavy brick walls. This building was destroyed by fire in less than sixty minutes. The insurance rate on that building was $1.65.

Insurance rates on manufacturing buildings range higher than on warehouses, because of the varied occupancy and the increased hazard. The manufacturing building at 171-173 Canal street, previously herein referred to, has a flat rate of 50 cents on the building and 75 cents on the stock. This is the lowest rate in Chicago on a manufacturing building. This building replaced also a mill construction building which was destroyed by fire. That building had a rate of $1.65 on the building and $1.95 on the stocks.

Mill construction has proven a great disappointment to architects, owners and the insurance companies, and while Mr. Atkinson, who proposed such construction, may have been able to produce first-class revenue for the New England Mutuals, he has not told us how to arrest the progress of a fire that has once gotten under headway in a mill-constructed building. This type of construction in large cities will undoubtedly soon become obsolete.

The two sections, Figs. 372 and 373, show the construction of the cinder concrete arches in the floor, and the fire-proofing of the column: the amount of cinder concrete underneath the lower flange of the beam; the character of the fire-proofing; and the depth of the floor at the crown of the arch, the arch being six inches in thickness at this point. The concrete up to an inch above the crown of the channel bar arch will be made as described, four parts cinders and one part natural rock cement, and from that point up to the Portland top, the cinder concrete is strengthened by the addition of one part of limestone screenings and the consequent reduction of cinders to that extent. This strengthens the floor and also provides a better bond between the cinder concrete and the Portland top. The Portland top will be about an inch thick, made of two parts crushed granite, and one part Portland cement, for the wearing surface of the floor. The columus are fire-proofed as shown in Fig. 375. The opened cylinder, which is set around the column in which the

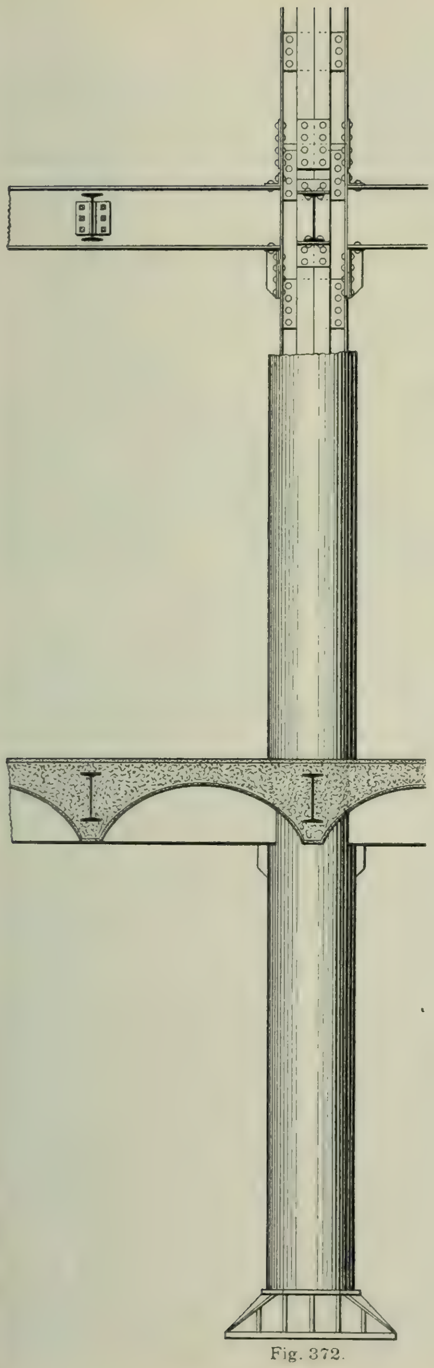

Fig. 372.

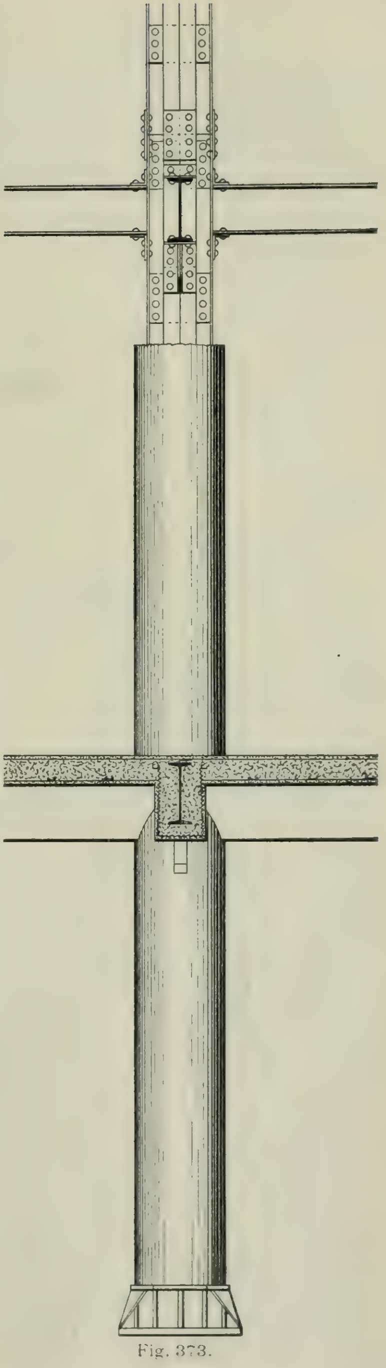

Fig. 373.

concrete is rammed, is shown in Fig. 376. After the cylinder has been removed and the concrete has set thoroughly hard, it is wrapped with metal lath, and plastered with 5/8 of an inch of hard mortar. The column section, Fig. 375, shows a portion of the concrete broken away, and the amount of concrete over the metal where it

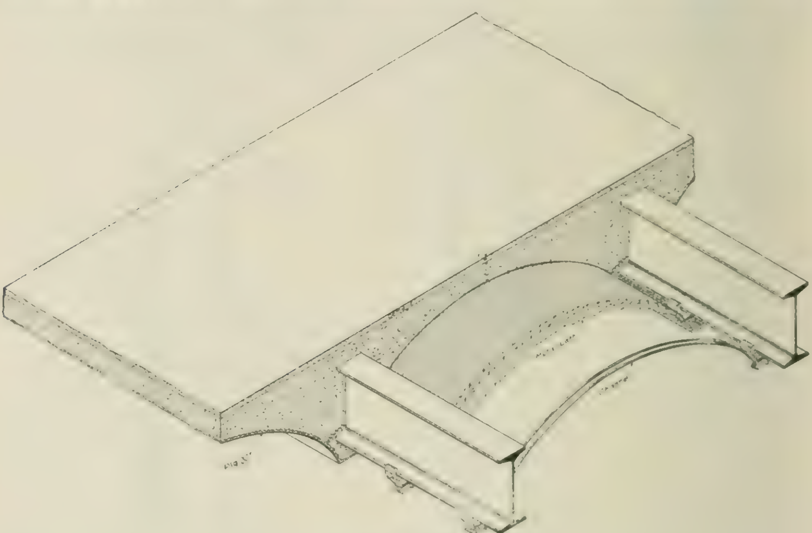

FIG. 374.

approaches closest to the air, which is, as I stated, four inches. The isometric section, Fig. 374, gives a clear idea of the floor construction.

The construction shown in Fig. 374 is the foundation of the concrete work. Cast iron clips are suspended regularly on the bottom flange of the beams, about fourteen inches on centers, and from these are sprung very light curved channel bars, weighing about one pound per foot. On top of these channels is laid a mesh of metal lath. This is primarily put in as a template on which to construct the concrete arch, but the other purpose of this lath is to provide a better bond for the hard mortar finish, as the value of this plaster lies in the hard mortar making a perfect union with the concrete. This hard mortar is carried around under the bottom of the beams as shown. Now, to provide against contingencies, the metal lath which passes down under the beam is a separate sheet from that which covers the arch, and is turned in under the concrete, where the concrete is built upon the flange of the beam, so as to prevent any possible displacement of the fire-proofing of the beam.

As to the strength of this construction, it can be made any strength required. It is a question of the proportion of cement that is put into the concrete, but that question is of secondary in-

terest, because it has been found that concrete is sufficiently strong for all such purposes, as it is now being used for the heaviest kind of work, and in the building that I referred to before, the Felix & Marston warehouse, there is a drive-way floor that was built about three years ago, and has been in con-

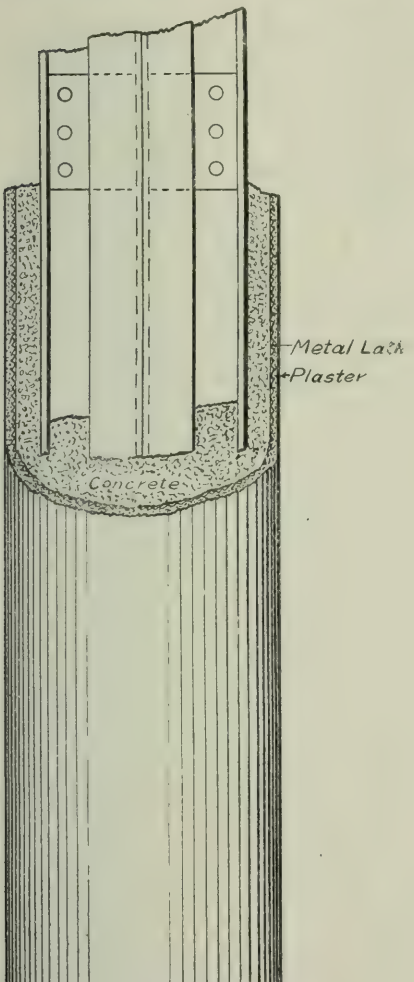

FIG. 375.

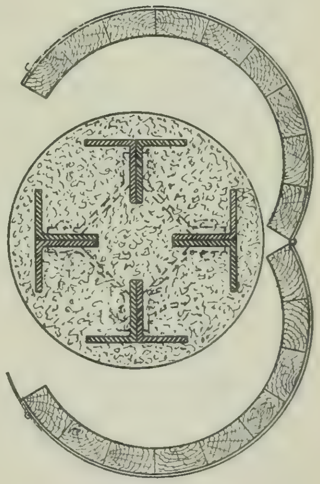

FIG. 376.

stant use for the heaviest kind of teaming for that length of time, and it has shown no evidence of failure anywhere, excepting that the Portland top has been worn through from the heavy shoes of the horses and the tires of the trucks. Otherwise the

concrete is intact; there was no strengthening of the concrete in that building. The concrete was made of four parts cinders and one part Louisville cement, without any sand or other materials.

DISCUSSION.

Gen. Smith: The arches shown in Mr. Abbott's sketches, it seems to me, are covered with cinders up to the level of the top of the beams, and finished out as the section of the finished floor shows. This whole space is filled with cinders (indicating). That gives tremendous weight to the floor, amounting, as Mr. Abbott says, to thirty-four pounds per square foot. I do not think that is necessary. I believe a very much better system would be to put a flat sheet of metal lathing from side to side, thoroughly secured to this, and strengthened if necessary by angular T irons, both top and bottom thoroughly fire-proofed by proper plastering, and protected from corrosion. A floor laid on top of that, with thin flooring and the ceiling below, would be strong enough and perfectly protected, and would not be more than one-third the weight. At any rate I make that suggestion, and will be glad to hear from any one present who agrees or disagrees.

Mr. C. L. Strobel: I would like to ask a question. These arches are, apparently, not true arches, for the reason that no tie-rods are used or other provision made to take care of the thrust in an efficient manner. It is assumed, perhaps, that the thrust of the intermediate arches will be resisted by the adjacent arches, but the thrust of the arch which is next to the outside wall of the building would not be taken care of in any way. Even for the intermediate arches the thrust is not very satisfactorily provided for, because only a slight lateral yielding of the beam, such as will probably take place, will cause the arch to act as a combined beam and arch. These arches ought, therefore, to be considered as resisting, at least partly, by transverse strength. The question then arises, what is the strength of these arches, which, I believe, are six inches thick at the crown, acting in this manner. I do not know of any published tests on the strength of cinder concrete. It would be of importance to know its strength, both in tension and in compression.

I do not share General Smith's views as to the inefficiency of the present methods of fire-proof construction, and his criticisms are so general as to be hardly fair. It may be that the plaster with which he proposes to coat the iron work will be an efficient protection, but he does not furnish us evidence that this is the case, and until we know that this method is superior to the present method of fire-proofing, we shall have to adhere to the latter.

The floor construction is not dealt with at all in his paper, but, if I understand the general's remarks correctly, he proposes to use wirelath with plastering on top, but we should know definitely what is proposed.

This whole subject is an exceedingly broad one, and it is hardly possible to deal with it in an off-hand manner.

The Pittsburg fire of May 3 has been quoted, but that fire has distinctly not proven that the present system of fire-proof construction is radically wrong. It has simply shown that certain details can be improved upon. Notwithstanding that this fire was an exceedingly hot one, and the methods of construction used were not in accordance with the best practice, there was considerable salvage. The cases are almost innumerable of small fires which have taken place in the large fire-proof buildings where no damage has been done excepting to the contents of a room, and whatever may be said of the defects of the present system of fire-proof construction—and perfection in this line must not be expected—it seems to me that it cannot be questioned that this method of construction has been of inestimable value.

I quote from Mr. Purdy's valuable paper, entitled "Can Buildings be Made Fire-Proof?" published in the Transactions of the American Society of Civil Engineers, and which deals particularly with the Pittsburg fire, as follows:

"The expression 'fire-proof building' should properly be defined as meaning a building which will not burn, no matter how great a fire it may be exposed to from without, and which will confine an internal fire to any room in which it occurs without material injury to the rest of the structure. In this sense of the word buildings can be made fire-proof, and the fire at Pittsburg rather confirms that opinion than otherwise."

Birkmire, in his book, "The Planning and Construction of High Office Buildings," makes the following remarks in reference to this same Pittsburg fire:

"Passing to a consideration of the damage done by the fire to the more purely structural features of the several buildings, one is impressed at once with the splendid showing made by the steel frames. Not a single steel member can be said to have been torn from its position in the structure by the heat of the fire or the destruction of its protecting fire-proofing. In the Horne store building at least 50 per cent of the columns and floor beams were found partly or wholly uncovered, but only slight bends were found in two or three columns. The thing responsible for the damage to most of the injured steelwork in this building was the fall of the heavy steel water-tank from the roof, and this accident seems to have been due to the reprehensible construction of the tank-supports on the roof, which were of wood, that burned away and allowed the tank to crush on to the light roof-framing. The steelwork in the Horne office building showed no injury except for occasional bent floor-stringers, and that in the Methodist Book building did not seem to be injured at all.

"These facts appear to us to be very significant. Much has been said at one time and another regarding the horrible distor-

tion which might be expected should one of our modern steel skeleton structures be subjected to an extensive fire, and it is very gratifying to have these assurances refuted by practical test, if only to the extent afforded by the Pittsburg fire."

As regards the protection given to iron work by painting, we have every evidence that paint, properly put on and shielded from the direct action of the sun and the rain, and not subject to abnormal conditions, such as the influence of acids or electricity, will stand almost indefinitely. The investigations made by a committee of this society of the iron in the old postoffice* building show that in that case there was practically no rusting. It is unfair to cite the rapid oxidation which takes place of the iron work exposed to the direct action of the smoke from a locomotive engine as having a bearing upon what may be expected in the case of a building. The conditions are entirely dissimilar. Paint exposed in close proximity to the smoke of a locomotive engine is destroyed largely by abrasion; the action is similar to that of the sand-blast.

The question of expansion has been alluded to. Iron and Portland cement have nearly the same rate of expansion for low temperatures and an almost identical modulus of elasticity, and one of the secrets of the success of the many examples of concrete-iron construction lies in these peculiarities. For high temperatures, there no doubt will be dissimilarity, and the conductivity, as has been stated, is not the same, but the practical test of use has shown that these types of construction are fairly satisfactory in their general features. This does not mean that they cannot be improved in detail or that all examples of fire-proof construction have been carefully and conscientiously planned. On the contrary, we know that this is far from the fact. As to whether it is advisable to provide expansion joints for temperature changes in building work, that is a question which would have to be decided for each individual case. As a rule, it is far simpler and the details are more satisfactory if the changes from temperature are allowed for in the strains which they will produce without providing expansion joints. That is no more than is done in the case of iron arched bridges of the two hinge type. These strains in buildings of the usual proportions are small in amount, and can generally be ignored.

The Chair: Mr. Abbott, have you anything to offer in regard to the strength of floor arches, built of concrete, in answer to Mr. Strobel's inquiry?

Mr. Abbott: Yes, I tested some of the concrete, as to strength, at the Dearborn foundry about three years ago. I built two arches; one had a corrugated iron template under it and the other had nothing. These arches were four feet span; that is to say, the beams were four feet apart and the arches were similarly

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*See Report in Vol. II, No. 4, Journal W. S. E., 1897.

loaded with about 10,500 pounds. We used the base plates of the Metropolitan road that were then being made at the Dearborn foundry. Those base plates are two by two and one-half feet square, and we piled them up as high as we could on the arches and got a load over 10,000 pounds on each of the concrete arches, over 2,000 pounds per square foot. Also, for a shock test, we dropped a 3,500-pound weight five feet, and in the case of both arches it was necessary to drop it twice before it went througn the arch. But I will say with reference to these arches, that building them as they were built, two isolated beams, without any end connections, that we had to put tie rods on them to hold them in position, and consequently the tie rods had some bearing naturally on the result. The result, so far as it went, would tend to show what is the compressive strength or rather the value of the cinder concrete in resistance to compression. There was no sign of fracture whatever under the quiescent load.

But replying more particularly as to the tensile strength of cinder concrete, I have no record and I do not know that any has been made, but it is a question, as I said before, of the kind of cement and the proportion in which that cement is mixed with the other ingredients, and as I stated in my paper, I consider the question of strength of secondary importance, as we have had so far sufficient strength in concrete floor arches, and I believe that it is a simple mechanical problem that can be met without any difficulty according to the conditions of the building where it is used.

Replying to the question about the lateral resistance of the beams for these arches, I think that the reply to that was outlined by the gentleman himself when he said that, aside from the outside spans, probably the concrete construction would be of sufficient resistance to take care of the load without tie rods; in the outer row of beams of course it might be necessary to take care of the thrust, and that I shall always do if necessary. We will place tie rods, or rather straps, across the beams to take care of the thrust at this point. But the rise of these arches which are illustrated on the screen, is twelve inches; it is a pretty good arch for the span, and the result is to carry the thrust well down toward the perpendicular, that is, very much more so than would be the case in a clay tile arch; the line of direction of the thrust is turned down toward the perpendicular, and in that respect the lateral thrust is much less, but so far as the interior arches of the building are concerned, the monolithic nature of the concrete will take care of the thrust without any difficulty. I speak of what has already been done. Of the two buildings mentioned in my paper, one of them is two years old and the other three. One of them is a manufacturing building in which there are some concentrated machinery loads, and in no case has there been any indication of failure of the arches by reason of the fact that there were no tie

rods, and I assume that aside from the outside arches there would be no necessity for tie rods in proper construction.

Mr. Pond: How long were the beams in span?

Mr. Abbott: In the building they would be fifteen feet.

Mr. Pond: Does not the mass of concrete around that beam form a beam in itself to take the lateral thrust?

Mr. Abbott: It does. To what extent we can only tell by determining the strength of the concrete.

Mr. Pond: But the fact remains that it does so?

Mr. Abbott: Yes, the fact remains that we have manufactured out of a concrete a beam with the steel beam imbedded in it.

Mr. Pond: That answers in a measure General Smith's objection that there is too much weight in there.

Mr. Abbott: I do not undertake to answer that objection, because I believe that the weight of thirty-seven pounds is lighter than any arch that I know of that will carry a similar load; that is to say, it is lighter than tile that will carry it, or terra cotta, but in using cinder concrete I do it because it is a light material, comparatively speaking, and in the arch is used for the two purposes of fire and rust proofing. The cinder concrete is to be used in compression only; that is to say, the tensile strength of it should be drawn upon only at the last moment, but I put it in in that shape because I want to thoroughly fire-proof the beams and obtain what is a safe floor construction. I, however, concede what General Smith says, and that is this, that if there was suspended from those beams sheet metal which would carry the load and on that was built a proper fire-proof floor and the beams were protected from rust and from fire by any other method which will absolutely do it, then there is a betterment of the conditions, provided that it can be done for the same money. Economy is one of the things that must be observed in building construction. Now, this is the most economical fire-proofing in the world, the details of which I have shown this evening. I do not make any exception of any kind. It has been demonstrated, and it is because of the way in which the work is done, and the low cost of the material cinders cost only 15 to 20 cents per cubic yard, and you can not get anything that has been tested by fire that is any cheaper. To use the General's method would lighten the floor construction, but whether it would cheapen it I do not know, or whether it would fire-proof the metal and prevent corrosion I do not know. If it would, then there is a better fire-proof floor.

General Smith: I do not claim that as to my method at all, but I desire a kind of floor and ceiling made in that way, and you have given us the opportunity here that I think is a happy one, leading to a discussion of this matter of economy.

We all know that we are properly prohibited from indulging in any useless extravagance in any of our works, engineering or architectural, but I think it is high time that the members of

both professions take this ground—that sound economy often requires the expenditure of a little more money; that there is an unwise and dangerous condition of things growing out of the avarice of the owners standing back of those of us who do the work, and it is high time that we should say, "Gentlemen, you are too stupid to see your own interest." We all do know that a small expenditure of money in securing perfect fire-proofing is very wise, even in addition to what would usually be expended. For instance, it lessens insurance rates sufficient to recoup the amount in a year or two, and the first great requisite that we should insist upon is the absolute safety of the structures that we plan to erect. This is first and foremost. Secondary to it, and important in itself, is the saving of money, but it should not be allowed to take precedence of the great requirement. I think every one of us owes it to himself and to those who employ him to stand out in favor of expending money enough to make the building safe and secure. Now I know there is a system such as I alluded to, through placing a horizontal lathing, top and bottom secured to the beams, strengthened if necessary by angle iron or T. iron, giving all necessary strength, thoroughly imbedded in a plaster that prevents corrosion and is a thoroughly fire-proof material. There are several kinds of this plaster; there has been a great improvement made in it recently, we will soon have an abundance of it for fire-proofing purposes. I believe the system proposed is better than the one shown here. I do not think it would be quite as cheap, I think it would cost more money, the metal part of the lathing above and below might exceed the cost of the arches as shown.

Mr. Abbott: How would you protect the beams underneath the floors from corrosion?

General Smith: The very first thing I would do after putting up the skeleton of the building would be to protect all parts of it by plastering.

Mr. Abbott: I would agree with you if that is successful.

General Smith: It is. There are several kinds of plaster that adhere splendidly to metal, and they would protect perfectly.

Mr. Strobel: Have you anything to show how thick the plaster must be used?

General Smith: You can hardly get it off with a cold chisel. There is a plaster made of talc, hydraulic cement and lime; talc is chemically the same as asbestos; they are both silicates of magnesia, and the talc mixed with hydraulic cement and applied to a beam with enough quick lime gives you a plaster that is cheap and adheres.

A Member: Have you anything to show that it does adhere?

General Smith: I have.

A Member: How thick is it?

General Smith: Not over one-eighth inch.

A Member: Spread all over the iron, inside and out?

General Smith: Yes. I recommend to all of you who feel an interest in this subject to make experiments of your own. Take the very refractory substances that you know of and mix them in various proportions and test them with heat, and you will find it very interesting and profitable. Test it as you can, and if numbers of us work in that direction, we can do more than one can alone. It is a fine thing for a man in any profession to co-operate and bring out such facts, making known the results of his experiments, asking questions and answering them. Fire-proofing is a great thing that we ought to work out, and work it out completely. We have made wonderful progress during the last two years.

Mr. Condron: I desire to state that, having become familiar with Mr. Abbott's system of fire-proofing I, as chairman of the Committee on Papers, invited him to describe the same in a paper before this society. I felt that the members of our society would feel greatly interested in seeing what one of our architectural friends had accomplished, and so urged Mr. Abbott to favor us with a paper, which finally he kindly consented to do.

I notice there is one very marked difference between General Smith's recommendation for fire-proofing and that described by Mr. Abbott. In General Smith's paper he proposes to paint or plaster the columns, and, as I follow him, form a second coating or shell of plaster around the columns on wire cloth or expanded metal, leaving an annular air space between the columns and the outer shell. The main difference being this air space between the outer coating of the column and the column itself, the column, however, being protected from corrosion—or I judge that to be the object of this plaster—on the inside. I would like to ask the General why he would recommend that air space rather than filling in and around the column with concrete, as done by Mr. Abbott?

General Smith: To get all the necessary fire-proofing in that way without anything like the weight. Neither do we take up as much space. There is an idea that half of us have not known the value of—I believe now that either by exhaustion or compression during a fire, cold air can be circulated through the whole frame in the spaces between the expanded metal covering that should be put on and the solid members themselves, and in that case the temperature would be kept down wonderfully. It must be borne in mind that if you simply plaster your skeleton as I suggest, you would get a pretty good fire-proofing; it takes pretty high temperature to affect the column or beam that is protected in that way, and it takes a good long time to do it. The city fire department says: "If you will only delay the fire, if you will only give us slow combustion, we will answer for any great fire. If you will only give us time to get there and get our engines into play, we will answer for results." Where we have not the means to go ahead in the way we have been talking about to secure the

best possible fire-proofing and prevention of corrosion, if we will simply produce slow combustion, we will do a wonderful amount of good.

Mr. Condron: I wish to ask Mr. Abbott if he can give us an idea of how much his fire proofing weighs per lineal foot on ordinary sized columns?

Mr. Abbott: The cubic foot would weigh about sixty pounds.

The Chair: What is the span of the arches which you use, what distance apart do you place them?

Mr. Abbott: Four feet, six; these illustrated this evening.

The Chair: This is about your usual practice?

Mr. Abbott: Well, it would not make any difference as to that; it would depend upon conditions. They might be three and one-half and they might be seven feet. In the event of their being wider, the concrete material would be of a different nature. That is to say, it would have to have more tensile strength to conform to the requirements.

Mr. Boardman: Under the direction of Mr. T. T. Johnston, assistant chief engineer of the sanitary district, I made some tests of neat cement and cement mortar and sand with regard to the effect of heat. We heated briquettes, made for ordinary tensile tests, by laying them on a perforated sheet iron plate placed over a gas flame, so that the flame came in direct contact with the briquettes and heated them in some cases to red heat, or as hot as we could get them. They were left there for several hours to cool, and later tested by tensile tests. The strength of these briquettes, compared with the strength of briquettes tested in the ordinary way, was greatly reduced, and the neat cement was affected worse than the cement mortar, as I remember. Nearly all the kinds of cement we had under tests, we tested in that way, and the results of these tests were published in the Engineering Record in the fall of '96. These tests seemed to show that the richer we made concrete, that is, the more cement in proportion to cinders, the less resistance it would have to fire, so that the cinders and lime added to the concrete Mr. Abbott referred to would seem to give fair resisting properties.

A. S. Coffin: I would suggest that some valuable information regarding tests of concrete spans could be obtained from Mr. A. L. Johnson of St. Louis, he having made a number of experiments in connection with the system devised by him.

Mr. T. T. Johnston: It occurs to me that the point raised by Mr. Boardman has quite a little bearing upon the subject of the fire-resisting property of this cinder concrete, that is, it is largely a matter of compactness. We find large masonry bodies, like lock walls, that are built in as compact manner as is possible for man to build them, that will not stand the variations of temperature that we ordinarily meet day after day in the year. Such masses of masonry will crack, in other words, rupture. So in neat cement briquettes or natural cement which possesses elements

which will cause rupture, such as free lime for instance, when that cement is mixed with sand in the form of briquettes, it will not rupture, but it will probably weaken. It seems further that the question of the strength of the concrete as you find it one time or another, will depend upon its compactness. We may make a very compact concrete and have it subjected to change of temperature which will cause it to weaken, and with a subsequent change of temperature it will have less strength than it had before. It is very probable, too, that the cement which may have a low elastic limit will not be so much affected by a change of temperature as if it were more compact. The question of compactness seems to be not only in the strength, but also in the fire-resisting properties. Mr. Abbott states that the concrete he uses weighs sixty pounds to the cubic foot, whereas ordinary cement mortar would weigh twice that, which would indicate a high porosity in the concrete. There is nothing inherent in the cement that makes it valuable as a fire-proofing material; it is simply, as I understand it, because that with the combination of cinders a mass is made which contains a certain amount of pores, or space, and this material is probably found, under certain circumstances, to be a good fire-proofing material, while under other circumstances it might not be, and it is a question of the particular connection in which the fire-proofing material is used.

Oscar Bluemner: After General Smith has in his former paper pointed out the insufficiency of our fire-proof materials and stated the necessity of progressive application of such which will answer the constructional conditions, as he summarized them, I want to add what I, as an architect, believe is necessary to fully consider the question of fire-proof construction.

I wish to consider this subject from that point of view which the architect will never renounce; that is the one of design. Any question of material or of the way of its use in buildings, that is of construction, directly touches the question of form or architecture. For architecture is but the result of material as well as other conditions and style is, as defined by a most eminent critic, the congruity between form and the process of construction, the qualities of material and all the requirements and conditions underlying a design. I believe that nothing more conclusive can be argued for or against any system of construction than the result of logical analysis of the style it produces.

The definition of style as conformity of form to the conditions of its origin, we commonly call the principle of truth. Such truth is bespoken by the Grecian style of stone construction based on the lintel and post system which was derived from the wooden frame. Another true style is the gothic architecture developing the proper principles of stone construction, viz: arch and buttress.

We have today a new system of construction of which iron and steel are the constructive material and other materials cover it.

The one carries, the other is carried; the one is heavy, the other light, as a statical consequence. If we apply the principles of criticism to the style of our modern industrial buildings of the so-called skeleton character and essentially of American origin we must confess that as yet no true style has been developed. There is *no* conformity between the principle of construction involved and the architectural design or form of our high buildings. Not one building has as yet been produced which bespeaks that truth of style I have spoken of; although there are at least in a few buildings in Chicago some indications of a solution of the problem. I consider the architecture of the Fisher Building, the Reliance Building, and still more of a more recent building on State street, and especially the efforts of Sullivan, as progressive.

But no pronounced features of a new style of industrial buildings have come forth. Indeed it seems the influence of the architects of the French school in the East, especially in New York, aided by the tendency of owners of high buildings toward monumentality, is the cause of the present retrograde evolution of the style of our commercial architecture.

This process consists in applying the forms of historic and highly *monumental* styles of the Roman and Gothic, that is their columns of stone and heavy reveals of arches and so forth to the skeleton frame of steel and to buildings of an *economical* type or covering the members which support the building with forms and masses of stone, which are likewise meant to support instead of being supported; hence the incongruity and absurdity of this style of our high buildings. Yet their essential system of construction has come and will stay, and as it is deeply rooted in our industrial and mechanical conditions, this modern system will spread over the whole field of building with the cheapening of materials.

A true style can therefore only be developed by fully complying with the principle of truth in design. The cause of the faulty, incongruous, expensive and ugly style of which our industrial buildings suffer is two-fold, if the ability of their designers be properly not disputed here; namely, first, the demand of the owners to get showy and attractive exteriors of their buildings, as also the conservatism of the majority, and especially business people, in the way of what they consider costly experiments. Secondly, and which is more important, the character and the qualities of the materials which the architect has to choose from for covering the steel frame. For it may be said that it is not the architect's proper business to experiment and discover new materials, but simply to look out for, test and apply them.

Stone and brick then may be considered as unsuitable to cover and give architectural form to steel construction, at least in industrial buildings. That is proven by the buildings we see everywhere, especially when such materials are employed above a

ground floor or several lower floors constructed entirely of iron and glass. The "Fair" is a conspicuous instance. Terra cotta has as yet given little satisfactory, at least no convincing, result either as a first-class fireproof material, or from an artistic point of view. Metals alone and without fire-proofing intermediate matter are too expensive or little suited, while tile and mosaic are little tried as yet and seem more adapted.

It is not enough to regard merely the fire-proof, waterproof, elastic and durable qualities as the necessary requirements for the covering materials of steel construction; they must possess such qualities besides, which will conform to true style.

The modern architect, taught by his former failures, has to look out for new fire-proof materials. The *first* condition for these is, in order to develop a progressive style, *lightness*. This condition simply and imperatively results from the comparison of its statical position. As we have seen, the fireproof material does not carry, it is carried.

Secondly. The material must be such that it can be easily moulded so as to yield closely to the iron members of the skeleton frame. Otherwise it will assume a form of its own fashion or of any arbitrarrily chosen historical style, instead of expressing the functions of steel.

Thirdly. The material must easily adapt itself to coloring process, of a durable kind and so that it can be easily cleaned, which is necessary in the smoke-laden atmosphere of our cities. I consider color and colored ornamentation as the only substitute for the depth of stone reveals and the consequent variation of light and shadow and relief which *stone construction* possesses as a characteristic element, but which the *steel system* of modern industrial buildings excludes.

The fourth condition is that such fire proof material which will answer all the constructive and artistic requirements must be cheap, comparatively, in order to be entirely satisfactory and find universal application, for true style always embodies economy.

T. L. Condron: I have been deeply interested in reading over the paper of Gen. Smith and Mr. Abbott. I think we would all like to learn from Gen. Smith something more definite regarding the tests of asbestic. That is, how these tests were made, and the duration and intensity of the heat to which the plaster was subjected. Was the plaster simply tested by placing samples in the flames, or was a structure especially built for a fire test? Also, it would be interesting to know if the tests at Montreal, New York and Washington were similar to each other and to the Chicago tests, and if not how they differed?

Regarding the weakness of steel at red heat there should be taken into account the impossibility of heating any considerable portion of the steel work of a building to red heat. In fact the point of failure for any fire proofing has been reached and passed

when the metal it covered becomes red hot. It is a well established fact that iron and steel increase in tensile strength and elastic limit with increase of temperature up to about 600 degrees Fahr. Tests at Watertown Arsenal show the following for steel of 0.20 per cent. carbon:

Temperatures Fahr.	0°	70°	210°	600°	1000°
Tensile Strength,	72,000	70,000	66,000	8,000	46,000

Until some clearer information can be given regarding fire-proofing with asbestic plaster certainly one would not feel warranted in substituting it for some of the present accepted methods of fire-proofing with porous tile or concrete, which have stood with fairly satisfactory results the test by fire.

In reference to the system described by Mr. Abbott there are features open to question. One of these has already been mentioned by Mr. Strobel, namely, whether the concrete arches should be considered as arches or not in determining the strength of the floor. The point raised by Mr. Pond that the mass of concrete surrounding each steel beam makes a combination concrete beam very stiff laterally and having a steel core, thus taking care of the side thrust of even the outside arches. Mr. George Hill, in a paper before the American Society of Civil Engineers, April 6th last, gives the results of a large number of tests upon cinder concrete. He says "it is the author's judgment that a fair value for the *ultimate* compressive strength of a fairly well mixed cinder concrete in the proportion of 1, 3, 6 should be 400 lbs. per square inch" (using Portland cement); and again he states, "considering that it is well to be conservative in all cases in the use of a new material the author has used as his constants for safe working strains of cinder concrete in compression 75 lbs. per square inch, and for stone concrete in compression 150 lbs. per square inch." He takes the safe working tensile strains at one-fifth of the compressive strains, namely at 15 and 30 lbs., respectively.

Prof. J. B. Johnson, in his treatise on Materials of Construction, gives the results of cross-bending tests on Portland cement cinder concrete slabs 4 inches thick and 32 inches between supports, both with and without expanded metal basis. From these tests he found the modulus of rupture $= f = \dfrac{3\,u\,l}{2\,b\,h^2}$ to range in pounds per square inch from 88 pounds from a mixture of 1 to 3 to 5 without metal base to 575 pounds for a mixture of 1 to 2 to 5 with metal base, and 100 pounds for this latter mixture without metal base.

Mr. Geo. Hill states the weight of cinder concrete, as used in his experiments, to be 100 pounds per cubic foot as against 60 pounds which Mr. Abbott gives as the average weight of his mixture.

In Mr. Purdy's description of the Pittsburgh fire he states that the cinder concrete over floor arches disintegrated in the fire. This

so-called cinder concrete is often but a loose filling of cinder and rubbish to deaden noise, and is not to be confused with well-made cinder concrete, which Mr. Abbott states has stood the test of continued heating in a furnace under a boiler.

Gen. William Sooy Smith: I have embodied in my paper a report of the expert who has helped me, in which he states that he has tested almost every kind of fire-proofing now in use, in fact, every kind that we could hear of. We tested them thoroughly. The tests were made in this way:

Take, for instance, adamant. We would make up a specimen slab, generally perhaps one half inch in thickness and say six inches on an edge, a little plate of it. We would hold that in a hot flame until it was red hot and then plunge it into cold water. If it stood that test then so far, so good. We would then test it for its conductivity. Therefore, so far as those tests go, I am not alone in having made these experiments. They have been made in New York, in Washington, in Montreal; they have been made in Europe at a great many points, and the testimony coming from all testing in that way is uniform and coinciding precisely with the conclusions I have stated to you.

The test that I made here myself consisted in a construction of a little building, which was six feet wide, seven feet high and twelve feet long. Ordinary wooden studding was used, just a wooden frame was constructed and it was lathed on the inside with wire cloth, a portion of it; a portion with expanded metal and a portion between the studdings was filled with hollow tile; the whole of it was plastered inside with a thickness of about 5/8 inch asbestos plaster. That was finished on the inside partly with ordinary hard finish, partly with a finish made of a mixture of the ordinary hard finish with an equal quantity of asbestic and partly with asbestic only. Necessarily the ceiling and all was plastered, as I say. There was a very thin coat of the asbestic put upon the tiling placed between the studding. This structure was built right on the ground and there were eighteen inches of split hard wood, dry faggots put on the bottom saturated with coal oil. Then it was allowed to burn with a very intense heat. We had a chimney on the top running up ten or twelve feet, so as to make a good draft, and as the hard wood and oil burned, it was replenished constantly by throwing in more wood and more oil until the flames from the floor struck the ceiling constantly. After a whole hour of this burning, and after the structure had become intensely hot, then cold water was thrown by the bucketful through an opening in front. We had no means of throwing a jet upon it, which would have been better, but the fire was put out and it was chilled as suddenly as we could with bucketful after bucketful of cold water. Where the finish was of the ordinary hard finish, it peeled off; where it was of asbestic or hard finish, part of it scaled off, but where the asbestic pure and simple was used, there was not a particle of scaling or disintegration;

the plastering itself did not crack at all except where we passed from one portion of lathing to another; there were little cracks sometimes where there was an unequal expansion of the metal. The studding was not ignited at all. A portion of it I would say was lathed with wooden laths. Where this wooden lathing was heated, it stood the heat for about twenty minutes without igniting, after that it commenced charring and by the time the whole hour was up, the lathing was burned by the flames. In other places the lathing was not even discolored by the heat, showing where the plastering was not in actual contact with the wood, there was no ignition.

I do not know so well about the experiments made in Washington, New York and Montreal, except that I have with me here a description of those, such as were published at the time. In Washington a building similar to the one I mentioned was constructed and was ignited on the outside instead of inside; the fuel was piled around it, heaped right up, saturated with coal oil and the flames maintained for three-quarters of an hour, then a jet of water thrown over and chilled suddenly and there were no cracks at all. This was done in the presence of the officers of the U. S. supervising architects' office at Washington, the supervising architect and the best experts in the city of Washington. As to the result it was absolutely approved by the government and nearly 3,000 tons of it used in the plastering of the great warehouses in New York. That was followed out by other buildings in New York, and a number in Montreal are now plastered with the same. I claim, therefore, that we have discovered something; if we can get something better let us do it, but we have one article that is better than anything that I know of, one article that I assure you has done what I said was done. The structure in New York was similar. I saw that after it had been built and tested in that way and it was done without injury; the one in Montreal the same way. I have one now constructed up at the yards of Lehman & Kohlsaat that I expect to burn within a couple of weeks. I will be glad to have you all present and witness it for yourselves.

Mr. Frank B. Abbott: I anticipated some of these questions in the remarks that occurred in the previous discussion, and I took them up briefly in this way:

Two points were raised in the discussion of the system of fireproofing advanced in my paper at the meeting of this society on April 6th last.

The first point of objection was by General Smith, and that was as to the weight of the concrete. In answer to that objection I stated that it is the lightest fire and rust proofing material in use, and that if a lighter material could be found which would surely do the work and cost no more, then that would be a better material, and I wish to ask at this time what is the objection to the weight? Is it because we must have increased strength in

the steel frame proportionate to the weight of this material over a lighter one? If so then we are reducing the problem to a question of cost, and I take it there is where we will eventually land in discussing the merits of any system of fire-proofing, for if we should find several materials that answer all the requirements so far as protection to the metal from fire and corrosion and so far as strength and utility are concerned, then we will eventually select that one of the number which can be obtained for the least outlay. In other words, if General Smith's proposed method of fire-proofing, using asbestic as a paint, and afterwards covering the steel members with metal lath with a coat of plaster upon this, should prove a success so far as resistance to fire and corrosion are concerned, it would not be a better material than the cinder concrete unless it could be put in for less money, taking the weight and all other features of the concrete into consideration.

While discussing the merits of concrete as a fire-proofing material we must not overlook its value as a register to wind pressure and as a stiffener to the frame work of the building, and in this connection it would not be practicable to cover columns with sheet metal, leaving hollow spaces behind, unless this sheet metal had a protective covering or shield to save it from injury, while the concrete needs no protection. Again, it often occurs in the construction of columns, such as "Z" bar and other shapes, that there are cavities which do not admit painting, but which are readily concreted or grouted.

The second point raised was as to the strength of the concrete, and I refer to this point again, not because I consider that there is any doubt of its strength, but because I should like to hear the opinions of the members of the society upon this question, as there may be many ideas which will be of value as to the best ingredients and methods to be used in making concrete for fire-proofing purposes. Cinder concrete undoubtedly has low tensile strength, but, as I stated in my paper, it is a simple problem, and sand or limestone screenings can be introduced in making the concrete, in such proportion as required by the conditions. There is no cause for alarm upon this point. But what constitutes physically and chemically the best concrete material for the purposes of fire and rust-proofing is a pertinent question, and I should be obliged to the society for suggestions upon this point.

In taking up the question of fire-proofing, especially as I have done, that is, fire-proofing of steel, I did it because I found that in very many instances where fires occurred in buildings that had a fireproof covering of tile or terra cotta the same as this building here; that when the tile became heated and water was thrown upon it, it went to pieces pretty readily and exposed the steel to the action of the heat. I cast about for some material that would be as cheap or cheaper and that would withstand that action and

at the same time be easily and readily used, and in experimenting with cinders I found that there was a material that was accessible and on which no one had a claim greater than any other person, and that it required no plant to produce, and that could be quickly and readily applied to the steel framework of a building, and so primarily I made some tests as to the comparative strength of it, and in using it in floor construction I used it as an arch because I considered that in compression the cinder concrete is all right for the loads that come upon it.

As to the fire-resisting qualities, I referred to them in my paper at the last meeting of the society, and briefly, as Mr. Condron stated, with reference to some blocks which were made and burned under a boiler, or rather placed in the furnace of a boiler, to test the fire-resisting qualities, and there were, as I recollect, seven or eight of these blocks about six inches square and eight inches long, some of them had wrought iron imbedded in them, and one of those blocks is still in existence and can be shown. I will be glad to show them to any member of the society. This block had a round iron bar about two feet long and three-quarters of an inch in diameter laid across it. It was placed with the other blocks under the furnace of the boiler and the temperature was sufficient to burn the wrought iron; it destroyed fully one-half of the piece and the cinder concrete block was raised to pretty nearly white heat and it did not, after being taken out, disintegrate, and it seems to be getting harder. This test was made about two months ago, and it is much harder now than it was the day it was taken from the furnace.

But in advocating cinder concrete I only do it for the reason that I speak of here, that it, so far as I have been able to discover, is the most economical method that will surely prevent corrosion, and, as Gen.Smith truly remarks, if the fire-proofing material that is used in covering steel has a sufficient quantity of lime in it it will absolutely prevent corrosion, and in using the cinder concrete, I used it in the proportion of about four of cinders to one of Louisville cement, with the introduction sometimes of sand and sometimes limestone screening, and Louisville cement has about 60 per cent. of lime.

A Member: I would like to ask Mr. Abbott if he has tested the cinder concrete by heating it to redness and throwing on cold water?

Mr. Abbott: Yes, I have done it several times, with very gratifying results, and Mr. Bowden, the superintendent of ratings for the Chicago Board of Underwriters, with two other gentlemen, one of them an architect, made the same experiment two or three years ago, and as he related it to me, he said that they tested a piece of coarse terra cotta, a piece of hard clay tile and a piece of cinder concrete at the same time, and raised them to a red heat, as I recollect it, and plunged them into water, and he said that the only material that withstood that test was the cinder con-

crete; that the others went to pieces. What the proportions in that cinder concrete block were I do not know, but, as any of you will find if you attempt the experiment, it stands that test pretty well. Of course in making cinder concrete, it is to be pretty well rammed, the particles want to be brought in close contact. But there is another material which I use in connection with it which I referred to in my paper, and that was,—all this cinder concrete is covered with a metal lath of some kind, usually a wire mesh that is put upon the surface of the concrete, the exposed surface, and plastered with a coat of hard mortar composed of about equal parts of natural rock cement and lime putty. That is done primarily to protect the concrete in the event of its being raised to a high temperature; if there should be expansion sufficient to cause it to flake off, the metal lath will take care of that condition. Secondarily that is put on to make a better key for the mortar finish. Now that coat of mortar, when it has been applied to this concrete with that metal cover, unites with the concrete and forms a surface that is pretty hard to heat through; it is very hard to affect it with any ordinary temperature, certainly with the temperature that would be raised in a building that was constructed of fire-proof material. Of course if such a piece of concrete was put in a building that was built of wood and would be subjected to the furnace heat that would be caused by several floors burning away, it might be raised to a dangerous temperature, but the temperature in a building covered with fire-proof material is rarely raised to such a point. The point in fire-proofing, I take it, is that it should withstand any sudden heat and the opposite test of cold water being thrown upon it.

Mr. W. R. Roberts: Mr. Abbott has raised the point of cost as between the different systems. It would be quite interesting to know the cost per square foot of floor construction such as he employs in the Felix & Marston warehouse.

Mr. Abbott: It cost in that building, as I recollect, about 9 cents per square foot.

Mr. Roberts: That was the entire construction, excepting the iron work?

Mr. Abbott: Yes.

Mr. Roberts: Did that include a flat ceiling underneath or not?

Mr. Abbott: No, there was not a flat ceiling in the warehouse. In the Druecker warehouses now being built, the cost of the floor construction (and we are making it as good as we can) is exactly ten cents per square foot of floor surface, without flat ceiling; that is, with the curved steel and plastered with fifty per cent cement and fifty per cent lime mortar, and that includes also the wearing surface of the floor, which is about one inch thick; it is Portland cement one part and crushed granite two parts. That ten cents covers the total cost of floor construction and the arch construction between the beam. Now if you compare that cost

with the cost of tile or terra cotta floors, you will find that it ranges twenty-five per cent to forty per cent less than for tile arches or any sort of tile floor construction carrying equal loads.

Mr. Roberts: Is it true that lime flies to pieces with water thrown on it?

Mr. Abbott: Not in my experience, no. The ordinary lime mortar with which we plaster our buildings is a very good fire resister.

Mr. Roberts: In Gen. Smith's tests, he states that that hard finish all flaked off.

Mr. Abbott: Undoubtedly it would under those conditions; that was a remarkable condition, but I do not find that lime and water generally fly apart. Taking it as I used it in this fire-proof construction, it passes through the metal mesh and enters into the interstices of the cinder concrete and it makes a key that it is impossible to dislodge under the action of heat. So far as my experience goes, lime as we use it for practical purposes does not fly to pieces.

Gen. Sooy Smith: I would like to state in a few words that the only experiments that I made on concretes of any kind, I have found no concrete that would stand the test, and for this simple reason, as I take it, a certain amount of silica is necessary to the induration of any hydraulic cement that is used. The induration of the hydraulic mortar is due to the formation of the silicate of lime and aluminum. Wherever silicon enters to any considerable extent into a compound, it will not stand heating to redness and plunging in cold water. We know that pure silicon will not. Take glass, for instance, and heat it even moderately and plunge into cold water, it flies to pieces and there is only a small percentage of silicon that enters into a compound which will stand that test. If the concrete that Mr. Abbott has tested stands that test, it is due to the fact that there is a much smaller percentage of silicon in it than is found in other concrete.

The question of weight stares us in the face. Mr. Abbott has recognized it. It is certainly true that we can get a metal structure with necessary stiffness and strength to resist any pressure whatever; as it is, steel is the strongest material known. I think that we can get that strength cheaper and better by the use of that material. It is not only an exceedingly strong material, but it is an exceedingly cheap material now, costing a great deal less than iron by modern manufacture, and I think if we can consummate the idea of making our building frames of steel, using steel with something to cover it which will protect it, we are reaching the ultimatum.

Mr. Roberts: There is one point that comes to my mind in regard to this discussson which I do not think has occurred to all members of the society, which struck me in reading the discussion of the last meeting at which I was not present. I think the fire-proofing system, if I may call it such, that Mr. Abbott

has set forth, is particularly adapted to the uses to which Mr. Abbott has put it; whereas, the system spoken of by General Sooy Smith is more adapted to some other uses. I think each system has its particular use. For heavy construction, such as warehouses, where the loads to carry are such as to require a heavier and more extensive system, the system used by Mr. Abbott would be preferable. Then the point was brought out that he did not have to use the flat ceiling, that it put in with his system it would raise the cost to the same as putting in some other system; but in premises where you do not have to use a flat ceiling, that system is better adapted than any other. The two systems seem to be rather confused, and I think that each of them has its use. For light construction such as apartment buildings and other uses to which we are trying to persuade the public to put fire-proof construction, the construction which Mr. Abbott uses would not be so well adapted, for there we have to put in a flat ceiling. The process he has named is rather hard to beat. We put in a good deal of fire-proofing material, and employ a good deal of cinder concrete in building, but we cannot beat that price in any system that I know of.

Mr. Abbott: I had overlooked one question which was asked that was relative to the disintegration of cinder concrete on top of the tile floor arch. Now, I want to say with reference to that cinder concrete that is used on top of tile floor arches for filling bears no relation whatever to the cinder concrete used as I use it. That concrete, if it can be called so, it is hardly worthy of the term, is simply a filling of refuse material, usually cinders and lime and the sweepings of buildings, which we have in there as a filling to bring up the level of the floors to the requisite height, and very little attention is usually given to the strength of the material, although it adds considerably to the weight of the building. There is a great difference between such material as that and one that is carefully proportioned and mixed in a good mixer, and put in place and carefully rammed and watched from the time the material arrives at the building to the time it is put in. In reference to that, I will say that the cinders we are getting to-day at that warehouse across the river are coming directly from the furnaces of the Edison Company, without being placed upon the ground at all. We are careful not to let any foreign matter get into the cinders, so that we get what we have been expecting to get.

ABSTRACTS OF PAPERS IN FOREIGN AND AMERICAN TRANSLATIONS AND PERIODICALS.

HOW TO BUILD FIRE-PROOF.

By FRANCIS C. MOORE, New York City.

(*From The Brickbuilder, March, 1898.*)

I think it advisable in an article of this kind, to state, as premises, certain propositions which might be treated as deductions. Some of them are axiomatic or self-evident, needing no demonstration, and ought to appeal to any practical mind as being truths, rather illustrated than demonstrated by the experience of the past few years. In accordance with this line of treatment, I desire to state by way of premise:—

First. It may be claimed that no construction is fire-proof, and that even iron and masonry could with propriety be designated as "slow burning." The iron or steel used in a modern building has, in its time, been smelted in a furnace which presented no greater capacity for running metal into pigs than some of our modern buildings, whose interior openings from cellar to roof correspond to the chimney of a furnace, and the front door to its tuyere. If a pyrometer could be adjusted during the progress of a fire it would be found to rise quite as high as in any forge.

Second. Glass windows will not prevent the entrance of flame or heat from a fire in an exposed building. It may seem strange that so obvious a proposition should be thought worth stating, and yet today more than 75 per cent of the "fire-proof" structures of the country have window openings to the extent of from 30 per cent to 70 per cent of the superficial area of each enclosing wall without fire-proof shutters. Heat from a building across a wide street finds ready entrance through windows, and the several fire-proof floors serve only to hòld ignitable merchandise in the most favorable form of distribution for ignition and combustion, like a great gridiron, to the full force of a neighboring fire. This was the case in the burning of the Manhattan Bank building, on Broadway, in New York, and of the Horne building, in Pittsburg. The latter building was full of plate-glass windows, 16x16 feet. Such buildings are not more capable of protecting their contents than a glass show-case would be. A recent article on the Pittsburg fire in the *Engineering News* aptly expresses this in the following words: "There seems to be some irony in calling buildings fire-proof which opposed hardly anything to a fire from across the street more sturdy than plate glass."

Third. Openings through floors for stairways or elevators, gas, water, steam pipes and electric wires, from floor to floor of fire-

proof buildings, tend to the spread of flame like so many flues, and should be fire stopped at each story. This fault is more generally overlooked than any other. Ducts for piping, wiring, etc., should never be of wood. In the Mills building, in New York, a fire, not long since, jumped through two or three floors from the one on which it originated, by means of the passageways for piping, electric wiring, etc., comparatively small ducts, but sufficient for the spread of flame. In one instance the fire skipped one floor, where it was cut off, and ignited the second floor above.

FIRE-PROOFING IRON MEMBERS.

In view of the fact that it is necessary to cover iron with non-combustible, non-conducting material to prevent its exposure to fire and consequent expansion, and in view of the fact that all ironwork, except cast iron, will rust to the point of danger, it is best to use cast iron for all vertical supports, columns, pillars, etc. It is not advisable, of course, to have floor beams of cast iron (except in the form of Hodgkinson beams thoroughly tested.) If a floor beam should give way, however, it might not necessarily wreck the building, whereas if a vital column should give way a collapse of the entire structure might result.

RUST.

At a convention held some years ago in New York, at which were present a greater number of experts in iron than probably ever met before or since in one room, there was not one who contended that cast iron would rust beyond the harmless incrustation of the thickness of a knife blade, whereas there was not one who did not believe wrought iron would rust to the point of danger; and there was not one who claimed to know whether steel would or not, each admitting that steel had not been sufficiently tested as to rust to warrant a reliable opinion. If it could be relied upon as rust proof, it would be superior to all other material for fire-proof buildings because of its great strength in proportion to weight. The use of steel in construction is growing, because it is cheaper than wrought iron, as lighter weights are used for the same strength, but while supposed to be superior to wrought iron, some of the prevailing impressions with regard to it are erroneous. Defects not possible to detection by tests are liable to exist in its structure. Among the first steel beams brought to the city of New York there were instances in which they were actually broken in two by falling from the level of trucks to the pavement, probably due to their having been rolled when too cold, as steel when rolled below a certain temperature becomes brittle. Better beams are now made.

In my opinion, cast-iron columns are superior to steel and more reliable. It is not generally known that American cast iron is vastly superior to English cast iron, and will stand a greater strain without breaking. Cast iron, moreover, will not

expand under heat to the same extent as wrought iron and steel, which is another fact in its favor.

COLUMNS SHOULD BE STRIPPED.

No bearing column should be placed in such a position that it cannot be uncovered and exposed for examination without danger to the structure. One of the ablest architectis in New York makes it a rule to so fire-proof his columns that they can be examined at any time by removing the fire-proofing to determine whether rust has invaded their capacity to carry their loads. In my judgment, periodical examinations should be made, from time to time, in this way of all wrought-iron or steel columns, as it may happen that a leaky steam or water pipe has worked serious harm. Such a discovery was accidentally made recently in an important New York building.

CEMENT AS A PREVENTIVE OF RUST.

Numerous newspaper paragraphs appear, from time to time, which claim that metal stripped of its covering of cement has been found exempt from rust, with the paint intact, etc., and the fact is cited as evidence that cement is a preservative of iron and that the danger of rust is over-estimated. It is probable that cement will protect paint for a long time, and, of course, paint, if properly put on, will protect iron while the oil in it lasts. Painting, by the way, should be done with the best quality of linseed oil and without the use of turpentine, benzine or dryers. It should be thoroughly applied in three coats, with about a gallon to 400 sq. ft., and the iron should be first thoroughly cleaned of rust and dirt, by pickling or other process. Paint is rarely properly applied, however, and even when of the best quality, is a preservative of the metal, as already stated, only so long as the oil in it lasts.

Those who claim to have evidence of the exemption of iron from rust rely, I think it will be found, upon iron which has been under exceptionally favorable conditions, free from dampness, the action of gases, etc., overlooking the fact that a leaking water pipe or steam pipe, or the escape of gases from boiler furnaces will attack iron and gradually but surely consume it. A notable instance of this is the case of the plate girder of the Washington bridge over the Boston and Albany Railroad, in Boston, where a quarter-inch plate girder was recently found to be entirely consumed in places from the operation of gases from the locomotives passing below.

It is quite common to have advocates of wrought iron cite railroad bridges and the elevated railroad structures of New York as proof of their claims, but if they will take the trouble to examine these structures they will discover that in spite of the fact that they are exposed to view, so that they can be painted frequently, the evidences of rust are unmistakable, especially about the rivets;

and one can well imagine what would be the result in the case of riveted iron members in the skeleton structure of a building where such iron work is entirely concealed from view, periodical inspections being impossible.

Rust is especially liable in the cellars and basements of buildings. The wrought-iron friction brakes of freight elevators in the cellars of stores, for example, are fequently found so consumed with rust as to be easily rubbed to pieces in the hand.

Steel rivets are dangerous and they should never be used, unless of a very superior quality, so soft that hammering will not crystallize the material, and yet with sufficient tensile strength to insure perfect holding qualities. This is difficult to secure. Their use in columns for buildings is objectionable, as they rust badly under certain conditions; columns, therefore, should be without rivets, and the beam-bearing bracket shelf on cast-iron columns should be cast in one piece with the column.

EXPANSION OF IRON.

It is generally supposed and frequently stated that there is a great difference between the expansion of iron and masonry by heat. This is not the case. For example, the length of a bar which at 32 degs. is represented by 1, at 212 degs. would be represented as follows:—

Cast Iron	1.0011
Wrought Iron	1.0012
Cement	1.0014
Granite	1.0007
Marble	1.0011
Sandstone	1.0017
Brick	1.0005½
Fire-brick	1.0005

In the fire-proof building of the Western Union Telegraph Company, in New York, some years ago, a heavy brick pier, 7 or 8 ft. in diameter, adjoined the wall of the boiler furnaces. The difference in expansion in the brickwork next to this furnace wall as compared with that of the remaining brickwork of the pier was so great as to produce a crushing of the material from top to bottom of the pier for a depth of several inches, and it was found necessary to change the furnace wall and leave an air space between it and the pier.

EXPANSION.

While the difference in expansion between masonry and iron incorporated with it is less per running foot than is generally supposed, and while the difference in expansion between a cubic foot of iron and that of a cubic foot of masonry would hardly be noticeable, especially if the iron were covered on all four sides, yet in stretches of 50 ft. or more, as in the case of iron I-beams and girders, the cumulative effect of expansion in uncovered iron

might be a serious matter—quite sufficient with the rises of temperature due to a burning building to push out the bearing walls and wreck the building. Especially is this true of temperatures higher than 500 degs. It is unnecessary to suggest that metal differs from masonry in the important respect that heat does not travel throughout the entire length of the latter, while it does in the case of metal.

In other words, while the difference between the expansion of a lineal foot of iron as compared with a lineal foot of masonry, marble, brick, etc., is very slight, the difference in conductivity is very great. The conducting power of silver, for example, being represented by 1, copper would be .845, cast iron .359, gold .981, marble .024, and brick .01—an important fact to be considerd in the construction of buildings. Brickwork raised to a white heat would not raise the temperature of other masonry in the same wall a few feet away but one end of an iron I-beam could not be raised to a white heat without raising the temperature of the beam for its entire length.

It is a well-known fact that iron responds so readily to temperature that, in surveying land, a surveyor's 100 ft. iron chain will, in measuring the distance of a mile, result in a variation of 5 ft. between winter temperature and summer temperature, resulting in an error of one acre in every 533.

Where iron beams and girders are inserted in walls without sufficient space left for their expansion under heat they are almost certain to overthrow the bearing walls by their expansion thrust. A large warehouse in Vienna in which such provision had been contemplated by the architect was totally destroyed, with its contents, by reason of the fact that an officious subordinate, discovering the space in the wall purposely left at the end of each beam, deliberately poured liquid cement therein, which, having set, effectually thwarted the well-meant intention of the architect, and resulted in the destruction of the building.

The expansion thrust of iron beams may be computed upon the following factor of expansion: Rolled iron of a length of 1,562 ft. will expand one eighth of an inch for every degree of temperature. The heat of a burning building as already stated is enormous—sufficient to fuse most known materials; it may safely be estimated to be at least 1,000 degs.; therefore a length of rolled iron of 1,562 ft. at 1,000 degs. of temperature would expand about 125 ins., and a 50 ft. length of iron girder would expand between 4 and 5 ins., showing that there should be a play at each end at least 2 ins. if the iron is not fire-proofed. Inasmuch as in iron construction the iron beams and girders are usually anchored to the walls to steady them, the space should be left and the tie to the anchor should be by a movable hinge joint which would be of the same strength with an inflexible anchor for all tying purposes but would yield under the thrust pressure like an elbow and allow play of the beam, or stiff anchors should have elongated holes to allow expansion when

beams are of great length. Girders are seldom over 25 feet long, but if bolted together, as is frequently the case, they may be 120 feet or more long, and a line of columns from cellar to roof of a building may easily have one continuous iron structure of 200 or more feet. It should be remembered, however, that this danger from the expansion of iron may be almost wholly counteracted by protecting it from exposure to fire through the use of non-conducting material. It is more important to protect girders than beams.

The mistaken pride with which the owners of some buildings point to exposed iron beams in ceilings as evidence that the floors are "fire-proof," actually justifying the supposition that they are left exposed for such display, would be ludicrous if it were not serious. In buildings occupied for offices or dwellings, where there is not sufficient combustible material to endanger the beams, it is not so objectionable; but in warehouses and stores, filled with merchandise, such construction is dangerous, and if one of the upper floors should give way it would come hammering down to carry all below and thoroughly wreck the structure.

In this connection it is well to say that combustible merchandise should never be stored 100 feet above the street grade, even in a fire-proof building, since the average fire department cannot reach it at that height.

* * *

STONE STAIRCASE TREADS.

Marble, slate, and other stones are certain to disintegrate or crumble when subjected to the joint action of heat and water. For this reason 90 per cent. of the staircases in modern fire-proof buildings would be found utterly unreliable in the event of fire, either for the escape of the inmates or for the use of firemen—a serious consideration. Stone treads are usually let into iron rabbet frames, and as these stone treads would give way in case of fire, it would be impossible for a person to find a footing on the stairways; 2-in. oak treads might actually last longer; but a safer staircase would be one the framework of which is of iron, the tread having an iron web or gridiron pattern, the interstices or openings of which should be small enough to prevent the passage of a foot, underlying the stone or slate, so that if the stone tread should disintegrate the staircase would still remain passable.

It is possible to have the supporting tread of open work cast iron in an ornamental pattern, which in relief against the white marble tread resting on it would present a tasteful appearance from the underside or soffit of the staircase, with this great advantage that, in the event the action of fire and water should pulverize the marble or slate tread, it would still afford a safe support for the foot. In the case of the burning of the two fire-proof buildings, Temple Court and the Manhattan Savings Bank in New

York, the slate treads yielded early in the fire, leaving staircases with openings the full size of the tread, which, within a few minutes after the fire started, were impassable for either firemen or inmates. It is astounding that this vital fault should be so generally overlooked in fire-proof buildings.

I may here state that the Manhattan Savings Bank building did not deserve to be called "fire-proof" for the reason that it had hollow spaces under the wooden floor boards, and that the iron beams and girders were not protected. Some of them were large riveted box girders, which yielded quickly to the heat of burning goods and pushed out the side walls.

It is generally supposed that it is not necessary to be careful as to stone treads in buildings occupied solely for offices separated in fire-proof hallways in which, it is claimed, there is nothing to burn; but in the case of one large fire-proof building of this kind in New York I found the space under the staircase in the basement story was used to store the waste paper and rubbish of the building—material particularly likely to cause a fire by concealed matches, oily waste, cigar or cigarette stumps, etc., and to make a lively and quick fire quite sufficient to destroy stone staircase treads. Even where there is no combustible material in the hallway, if the staircase is near windows stone treads may be destroyed by exposure to burning buildings and by the combustion of window frames, dadoes, and other wooden trim.

* * *

Enclosing walls. These should be of brick, the brickwork of the lower stories especially, if not of all, being laid in cement mortar. In fact, the specifications for a building in the compact part of the mercantile section of a city ought to be drawn in contemplation of the possible cremation of its contents and the generation of heat considerably greater than 2,000 degs. Fahr. The heat of a wood fire is from 800 to 1,140 degs.; charcoal, about 2,200 degs.; coal, about 2,400 degs. Cast iron will melt at between 1,900 and 2,800 degs.; wrought iron, 3,000 to 3,500 degs; steel, 2,400 to 2,600 degs.; and if an architect should be required to draw specifications for a building adjoining others with knowledge beforehand that its entire contents, from cellar to roof, were to be totally consumed, and he were under a bond to pay damages to surrounding property, he would not be more severe in his exactions than should a building law protecting neighborhood rights in the enjoyment of property; for a mercantile or manufacturing building sometimes generates a greater heat in combustion than a smelting furnace.

THE REFRACTORY QUALITIES OF CLAY.

By PROF. EDWARD ORTON, Jr., of Columbus, Ohio.

(*From The Clay Worker, Feby. 1898.*)

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Without attempting to go into the matter with any thorough-

ness, it can be said that a clay is a mixture consisting of the mineral, kaolinite or clay substance, with a very wide variety of other minerals, having no definite aggregate composition or proportion. The kaolinite may constitute nearly the whole of the mixture or it may be reduced in amount till it becomes insignificant. The accompanying materials vary similarly in character and amount, so that it is not possible to expect to find two clays which are exactly alike in ingredients and proportions.

The kaolinite has fixed chemical and physical characteristics which are well known and sharply defined. Among the latter plasticity is the essential one, and this quantity is so important that it alone forms the means of deciding whether a mineral mixture can be called a clay or not. If there is kaolinite enough, present to make the whole material plastic, we call it clay. If there is not enough, we call it sandstone, or limestone, or an iron ore, or a coal, according to which one of the mineral ingredients is the most abundant and important in its makeup.

These fundamental facts being understood, we can readily see why clays give a great range of refractoriness, for it is only reasonable to believe that each and everyone of the minerals entering into this complex mineral mass is certain to have not only its own individual pyrometric behavior, but also that it is certain to affect the pyrometric behavior of the other minerals with which it is associated.

We have before seen that some materials are bases and some acids, or some positive and some negative. And when we know that the commonest of all the associated minerals found in clays comprise the commonest of all negative materials, called silicia or sand, and the commonest of the positive elements, such as lime, magnesia, iron and the alkalies, we can readily see that we have no simple problem on hand when we try to forecast the refractoriness which any given clay may exhibit.

Before anything at all can be done in this direction, however we must, above all things, obtain a clear idea of the pyrometric qualities of the kaolinite itself, which is the soul or essence of the clay. As is well known to you all, clay substance itself, or kaolinite, as it has been christened by scientists, is a simple silicate of alumina, the simplest combination which these two compounds unite to form. Silica is the most abundant material in the earth's crust, and alumina is the next to it in the order of abundance. But while they are both present in innumerable other mineral forms, when mixed with other bases, they form together, few if any other compounds than kaolinite.

Silica and alumina are both almost infusible by themselves. We cannot melt pure silica, unless we deliberately go at it to make a furnace which will do so. It can be melted with difficulty by the oxyhydrogen blow-pipe, or it can be melted easily and even vaporized by the electric arc, but these generate temperatures which are beyond all common attainment and above all use

in the ordinary metallurgical and ceramic arts. So also with alumina, which alone is a little more infusible than silica, and which nearly vitrifies at the heat of molten platinum.

But compounds of the two elements rarely, if ever, retain the characteristics of their component parts, either in fusing point or in other respects, and, furthermore, the fusing point of a compound is in nearly all cases lower than the average of its components and often lower than either alone. To this, kaolinite or silicate of alumina is no exception, though there is less difference here than any other case which might be cited. Its melting point is lower than that of silica or alumina, separately, but only slightly, for it requires a temperature nearly up to the heat of molten platinum, at which silica also fuses.

The importance of this fact can scarcely be overestimated. Consider for a moment what it means to the economy of mankind on this planet of ours. It means that the one material which has been gifted by nature with the supremely useful quality of plasticity, by which we make it take any shape our hearts desire, has also been given the power to become practically indestructible as well; that we can harden into permanence anything which our necessities lead us to model and design.

Pure clay substance, therefore, is refractory. It cannot be melted except in specially designed furnaces, at temperatures above those in practical use. But, as has been already said, pure clay substance is never found outside of museum specimens. Clays are composed of proportions of clay substance ranging from almost complete purity down to very low and unimportant amounts, and naturally their fusibility flunctuates nearly as widely as their composition.

The refractoriness of a clay, therefore, becomes a study of how these ever-varying mineral ingredients will affect each other and how they will affect the clay substance by which they are bonded together. And here the same laws come into play inside the anatomy of the clay, so to speak, as were shown to act on simple substances when heated together outside. We saw that a silica brick which could not be melted by heat alone would fail in a few moments if a basic clay was allowed to touch it when hot. Similarly, a clay which unites several ingredients in one body, each of which is in itself infusible, may fail wretchedly at a low heat when the test comes.

We must, then, observe in a clay two things, if we would form an estimate of its heat-resisting powers. First, we must know how much of its substance is really composed of clay or kaolin; and, secondly, we must know what its accessory minerals are, and how much of each.

Not only must we know these facts, but we must also know how to interpret them when they are obtained. And here is the key to the whole subject, after all, in this interpretation of the effect of these different minerals on each other.

Let us consider a very few of the principal minerals which we are certain to find in almost every clay.

First and foremost comes silica, quartz or sand, as it is variously called. This is an omnipresent ingredient of clays. None can be found which are absolutely free from it, and in most it constitutes a large, and often the principal, part. Now, the common and accepted idea among clay-workers, until very recently, has been that silica is an advantage to the refractory qualities of a clay. Indeed, I doubt not that if a vote were to be had among this assemblage many of you, possibly the majority, would be found in possession of that idea. Indeed, it is more than likely that some of you would arise as champions of the sand and say—not without truth, either—that you know of your own personal knowledge and from results of your own personal experience, that sand increases the refractoriness of your clay.

This fact cannot be gainsaid, but it will be my endeavor in a few moments to show how this apparent contradiction can be satisfactorily cleared up.

Some few years ago this subject was studied by the late Dr. Seger, in Berlin, who, with that wonderful clearness and simplicity which characterize all of his work, has presented the truth to us in a way which will never require improving.

Taking a pure white burning kaolin, which will endure a temperature nearly up to the melting point of platinum, he mixed with it in aliquot proportions pure white silica. His mixtures had molecular formula and percentage composition shown in the following table:

TABLE I.

Chemical Formulæ.	Molecular Parts.		Percentage Composition	
	Clay.	Sand.	Clay.	Sand.
Al_2O_3 2 SiO_2	1	0	100.00	0.
Al_2O_3 2.5 SiO_2	1	½	89.60	10.40
Al_2O_3 3.0 SiO_2	1	1	81.19	18.81
Al_2O_3 4.0 SiO_2	1	2	68.34	31.66
Al_2O_3 5.0 SiO_2	1	3	59.00	41.00
Al_2O_3 6.0 SiO_2	1	4	50.72	49.28
Al_2O_3 8.0 SiO_2	1	6	41.84	58.16
Al_2O_3 10.0 SiO_2	1	8	35.05	64.95

From this but one deduction is possible, and that is that the silica has reduced the refractoriness of the clay. And as these are not theoretical considerations, but practical trials, there seems no escape from this deduction.

Seger's further experiments showed that silica reduces the refractoriness of a pure clay even up to the proportion of seventeen molecules of silica to one of alumina, or in per cents up till the free silica amounts to about 77.7 per cent. and the koalinite to 23.3 per cent. of the clay mixture. After this point the continued ad-

ditions of silica to the kaolin began to increase the melting point, gradually approximating to the melting point of pure silica, as the kaolinite becomes less and less.

It must be observed, however, that, after all, the total amount of this reduction in fusing point is not so very much in actual temperature. The whole of Seger's series, from the highest to the lowest, required temperatures greatly above that of a glowing whiteness. Indeed, the lowest point in this series is much above the fusing point of pure wrought iron or nickel, which requires 1500 degrees C. at the least, which is a heat far in excess of that used in most of the metallurgical or ceramic industries. So that these differences produced by sand on the fusing point of a clay would be of no importance, if there were no other minerals present than clay and sand, or unless we needed for some special purpose the very maximum refractoriness which clay can be made to yield

Unfortunately, purity is easily obtained in a series of laboratory trials, but not in practical work. We must use such clays as can be had at reasonable prices and in large amounts, and as such clays invariably contain other ingredients than clay and sand, we must look further into the matter before we allow free entry of sand into our mixtures.

To Dr. Richters, another German chemist, we owe the next important step in completing our information on the subject. In his now classic researches he showed, among other things, that while the various bases, such as iron, lime, magnesia and the alkalies, could attack and fuse even a pure kaolin at high temperatures, that their activity was very greatly stimulated by the presence of a little free silica or sand. Now that we know this fact, it seems only reasonable and rational that it should be so. We always feel so about great discoveries after some master mind has presented them to us. For pure kaolin is a silicate of alumina, already combined before the heat test begins. Moreover, it is refractory by and in itself. The presence of other bases, like lime and iron, is unfavorable, of course, but they did not find anything of opposite chemical affinity with which to combine, for the alumina has already gotten all the silica preempted. Hence, great heat and large quantities of fluxes are necessary if we expect to break down a kaolin in this manner. But suppose there exists free silica; we now have the two chemical sexes present; when the heat rises combination will naturally ensue, as neither base nor acid are attached chemically to the clay substance. As a result a fluid slag is formed which in turn acts as a solvent to the hot clay substance. Its operation is not unlike that of a lump of sugar whose lower surface is dipped into water and allowed to absorb by capillary flow until the moisture appears on its upper surface. If this lump is tested with a knife, it is still hard and sound, though damp. If it is set aside for a ew moments, it will be seen to have melted into a syrupy pool.

It seems incredible at first that the small amount of water in this hard lump of sugar would exercise so important an effect. And in a clay it is equally wonderful how far-reaching is the effect of a small quantity of slag-forming ingredients under high heat.

This, then, is the one first great law of refractory clays: "No clay can have high refractory qualities if it contains any appreciable quantity of free sand." For even if the clay contains naught else but sand, and if it will endure high heats when tested by itself, there still remains the fact, that contact with any kind of basic matter at any time when hot will result in the surface slagging and gradually wasting away, and as the dripping and flowing of the surface proceeds, new surfaces of the clay are constantly exposed to the fatal contact with bases. It matters not from what sources these basic substances may come. They may be slags or coal ashes or sparks of molten metal—their action is the same in any case.

This explains why so many clay workers have failed to reach success in entering the field of fire brick making. Scarce a month in the year passes in which some one does not write to ask my advice as follows: "I have a fine white burning kaolin clay and also a fine white sand. I wish to enter the fire-brick business, and would like to know how to mix these to the best advantage." They reason that clay is infusible and sand is infusible; that the shrinkage of the clay will be controlled by the unplastic sand, and that from the two an ideal brick will result. Not infrequently they refuse to accept the above principles as true, and persist in a trial before they are convinced. There are still other reasons which cannot now be taken up, connected with the shrinkage and physical strength of the product which prevent any mixture of kaolin and sand being well received in the trade.

BURNED CLAY AS A FIRE-PROOFING MATERIAL.

(*From the Clay Worker, February, 1898*)

* * * * A slow burning and fire-proof building are just as different as a brick house is from a frame one. A building made of steel beams, properly erected, filled in and protected with burned clay (hollow tile) can be made as fire-proof as the kilns in which we burn our brick and terra cotta, or the furnace in which the iron is heated to be rolled.

The only known material with which this can be done is burned clay, that is, hollow tile or brick. Of course this must be made properly, and if the tile is not made to cover the iron in the very best manner, and to stay there under all reasonable conditions, the desired result is not accomplished; or if it is made so light in weight and of such a brittle character that upon the least test it flies to pieces, then it is not of the proper kind.

Tile should be made with heavy webs, with rounded corners and of a porous nature, which then affords a material not only of

sufficient strength, but of a toughness which allows of contraction and expansion without injury to the material.

To make tile in this way means that the manufacturer must have a price which will justify him in using heavier material, especially where freight is one of the greatest items of cost, but this he seldom secures. It is usually the owner who is to blame, not the architect. The owner tells his architect he wants a building of such dimensions to cost so much. This cannot be built under a certain sum, but he thinks it can, and sometimes the architect agrees with him, knowing at the same time it is impossible, but, like all of us, he is anxious for business, and prepares plans and specifications, irrespective of the quality of the fire-proofing required, which, to my mind, is of the most important materials necessary in the erection of a building.

The specifications call for hollow tile, but no weight is specified; one manufacturer, if responsible, has just as good a chance as another; some one of them, having little to do and anxious for work, sharpens his pencil and figures how light in weight he can make his goods for this particular job. He reduces the thickness of his webs as much as possible, cuts out one or two and possibly all of them, and he finds his weight decreased per square foot, say, for example, ten pounds. What is his saving on 50,000 feet, which is an ordinary job? It is 250 tons, which at $3.00 per ton freight means $750.00 without considering other savings in his manufacture.

There is no question but what heavy tile will withstand the action of fire much better than light ones. This has been proven in actual experience, of which I will speak later. The light tile fellow secures nearly the same price as the manufacturer of heavy tile, who believes in making his corners round, his tile tough, not brittle, and in every way giving a better and stronger job. This should not be any more than the iron manufacturer has a right to receive as much for a ten-inch beam, one foot long, weighing twenty-five pounds as he does for one of the same depth and length but weighing forty-five pounds.

But such is competition among the tile manufacturers themselves. And the worst of all competition is what is known as concrete, plaster of paris, lime of teil and other so-called patent systems of fire-proofing, which have no more right to be called fire-proofing than the moon has a right to be called the sun.

However, will say here, there are very few architects who ask tile manufacturers to compete against such constructions as I have last named, as the great and learned majority will have nothing but burned clay for the purpose of fire-proofing buildings, which are to be living monuments of their skill and beauty of design.

These people of patents have nothing to lose and everything to gain; they need no capital, as the dealers supply them with their requirements in the way of necessary cement, lime, or plaster of paris; the cinders are given to them for the carting,

and their bills may be paid as money is received from the building.

Allow me to stop here and ask; have any of us present ever heard of a furnace, a cement, lime or brick kiln, or, if you will, the little range, fire-place or cook stove in our home being built of cement and cinders, plaster of paris, or of lime and sand? I do not think we have, and our answer is that these places, which have been named, are built of burnt clay materials, from the furnace to our little fire-place at home, yet these materials which have been mentioned are put in buildings for the purpose of resisting fire. Does it not seem absurd on the face of it?

How many of us have witnessed fires and watched every vestige of combustible material consumed in a building, yet the brick walls were left standing as a testimonial to their fire-proof quality? I say again, there is nothing like brick in a fire, and everybody is aware of the fact. What is hollow tile but brick made hollow?

Examine the ruins of a great conflagration, and what do you find? You find every vestige of wood gone, glass melted, iron warped and twisted, stone and cement pavements cracked, crumbled and gone to pieces, but the brick themselves, whether in the wall or cellar of the burned building, after having gone through the hottest of the fire, are just as good as the day they left the kiln of the brickmaker. These bricks were made of burned clay.

There have been many tests of fire-proofing materials, but it is of the actual ones only of which I will speak, and as the Pittsburg Terra Cotta Lumber Company, with whom I am associated, are manufacturers of both porous and dense tile, I can compare them without prejudice.

The actual fires which have occurred have proved much. There have been fires in many fire-proof hotels, among these the Holland House, New York City; Hotel Metropole (now the Walton), Philadelphia; Great Northern and Palmer House, Chicago; Stillman Apartments, Cleveland, and Hotels Lincoln and Henry, Pittsburg, all of which have had fires of greater or less magnitude, some having contents of rooms completely burned out, others their cellars badly damaged, others their store rooms destroyed, and who will venture to say if these buildings had not been fire-proof they would not have been burned to the ground, yet they were practically uninjured, as the fire only got as far as one or two rooms.

The first and only fire of any great magnitude which came to my notice as occurring in a fire-proof building was the one which damaged the Chicago Athletic Club building. Quoting from the "Engineering Magazine" of February, 1893, in an article written by Mr. Chas. H. Bibb, viz: "On the morning of November 1, about 1:30 A. M., fire was discovered on the fourth floor, but not until it had assumed such proportions that it appeared that the building was certainly doomed. To say that the fire burned until it

burned itself out sounds like a slur on the very excellent and efficient fire department of Chicago; and yet a visit to the scene and an examination of each separate floor demonstrated the fact that almost every particle of combustible material, not excepting the window frames bricked in the openings, was consumed. Such was the intensity of the heat that the surface of the fire-proofing material and the exposed face of the brick in some places on the fourth and fifth floors became fused, and the molten glass from the skylights in the courts on either side of the buildings ran down the walls like tallow grease. The chief of the fire department, in one of the newspapers, was credited with saying that he never saw a hotter fire than this very modern fire-proof building.

"The result to the building has been the complete destruction of the costly and beautiful front above the third floor, and, as before stated, the destruction of all interior finish in place and otherwise of both wood and plaster. It goes without saying that all iron piping and electric wires suffered the same fate. Here, however, the damage ceased. In its structural entirety the Athletic Club building remained apparently intact. The tile arches of porous terra cotta, set according to the very latest adoption of construction, namely, the 'end construction,' are practically uninjured by the combined action of intense heat and tons of cold water; not one arch has fallen, and the recent tests made on the worst looking arches developed a sustaining capacity of 450 pounds per square foot without sign of rupture.

"The partitions also of the same material were practically intact, and as originally built, except that every door, door-frame and casing, and all base, wainscoting and wood work of all descriptions entirely disappeared, and the plastering was completely stripped off, leaving the tile bare. The wood floors were entirely consumed, and in many places the strips bedded in the concrete to receive the floor, were burned completely through."

For information to those who are not familiar with this fire, will say that at the time it occurred, this building was in an incomplete condition. There were many thousands of feet of unworked lumber, which was to be put in place, piled on the different floors. Many of the most elegant rooms were to be, and had been, lined and paneled with hard wood finish, and this was what fed the fire. The tile arches in this building, after having gone through this severe test, remain there to-day intact.

THE COMPOUND LOCOMOTIVE IN THE UNITED STATES.

By William Ledyard Cathcart.

From Cassier's Magazine, November, 1897.

ADVANTAGES OF THE COMPOUND LOCOMOTIVE.

In considering the relative value of the compound locomotive,

it should be remembered that it is not a steam engine merely, but that it includes the boiler as well; and that the double-expansion principle has incidental, but important, effects not only upon the latter, but upon other factors of railroad economy. That the matter may be stated fully, there will be given herein not only the incidental advantages referred to, but the well known causes assigned generally for the superior economy of the compound engine *per se*, when compared with the single-expansion type.

There may be noted, first, the use, with economy, of high pressures.

The ability of the single-expansion locomotive to utilize increased pressures has not kept pace with the improvement in material which permits them, since its stroke, cut-off, and rate of expansion are limited, and its exhaust-pressure is now wastefully high. Initial pressures, it is true, have risen and have made engines more powerful; but exhaust pressures have grown with them, with, in consequence, greater waste. By compounding the engine, the rate of expansion is largely increased, since steam passes through, and is expanded in, two cylinders instead of one, thus making economically practicable the use of the high initial pressures of the present, with practically no waste, the power remaining in the exhaust being sufficient only for proper draught. Speaking broadly, then, the compound engine utilizes, in driving, the wasted power in the exhaust of the single-expansion engine; for equal powers, it must, in consequence, require less steam from the boiler, with a resulting saving in both fuel and water.

There is also reduction in cylinder condensation, owing to the relatively small variation of temperatures in the cylinders of the compound, as compared with that in the single-expansion engine. In the latter, during each stroke, the surface of the cylinder, one cylinder-head, and one side of the piston are cooled down to the temperature of the exhaust steam. The live steam, when entering, must heat these surfaces to its own temperature, condensing, and additional steam flowing in to take its place until this is effected. The range of temperature, and of loss, is then in both cylinders, that between the temperatures of the live and exhaust steam.

In the compound engine this range is, in each cylinder, much less. In the high-pressure cylinder it extends between the temperatures of the live and receiver steam only; and, in the low pressure cylinder, between the temperatures of the receiver and exhaust steam. Heat expended in warming cylinder walls is obviously lost in power, and, since the range of temperature is less in the compound engine, there is, with it, in this, a further saving.

As to the matter of combustion in the boiler, it is to be noted, to begin with, that the tractive force of a locomotive is the force which, coming down from the cylinders, is assumed to act on the circumferences of the driving wheels, tending to turn them on

their axes The resistance met by it is the friction between these wheels and the rails. The amount of this adhesion necessarily limits the tractive force, since, if the latter exceed the former, the wheels will rotate without advancing. The adhesion, in turn, although influenced by speed and weather conditions, is measured mainly by the pressure of the driving wheels upon the rails. Hence, the cylinder dimensions are proportioned to the weight upon the driving wheels.

With two locomotives, then,—one single-expansion and one compound, but both of the same size and type,—the boilers must be practically the same in each, since, other things being equal, the weight of either boiler can be such only as the intended pressure on the driving wheels will allow. Both boilers will have, then, equal heating and grate surfaces, but, as has been shown, the compound engine will require from its boiler less steam, owing to its increased rate of expansion and decreased cylinder condensation. There are possible with it, therefore, a milder draught, lower exhaust-pressure, slower rate of combustion, greater absorption of heat from the products of combustion, and a less temperature and resulting loss, in the waste gases of the smoke-stack. The economy noted previously has been that of the engine alone. It will be observed, however, that, in the slower rate of combustion practicable with the compound locomotive, there is a further and distinct saving within the boiler.

Professor W. F. M. Goss, in an able paper on "The Effect of High Rates of Combustion upon the Efficiency of Locomotive Boilers," has discussed the results of experiments carried out recently in the locomotive laboratory of Purdue University. He says, in part, as to the locomotive experimented upon and the coal used (Brazil block):—

"It appears that, when coal is burned at the rate of 50 pounds per square foot of grate per hour, 8 pounds of water are evaporated for each pound of coal; while, if the rate of combustion is increased to 180 pounds per square foot of grate, the evaporation falls to about 5 pounds—a loss in water evaporated per pound of coal of nearly 40 per cent. This loss may be due to a failure of the heating surfaces to absorb properly the increased volume of heat passing over them, or to the imperfect combustion of the fuel upon the grate, or it may be due to a combination of these causes. * * * The results show that the most efficient furnace action accompanies the lowest rates of combustion."

In summing up the total saving in fuel and water with the compound locomotive, we find that it arises from three sources, viz., the higher rate of expansion, the reduced cylinder-condensation, and the slower rate of combustion. These considerations affect not only the cost, and dead weight carried, of fuel and water, but more remotely, other matters to be referred to hereinafter.

As regards repairs and maintenance, the compound engine is subject to much lighter strains at the beginning of, and to less

variation in strain during the stroke than the single expansion engine; hence, the friction on journals and guides will be less, and it will run more steadily than the single-expansion engine. If the working parts are of the same dimensions in both, it follows that, with the compound, there will be reserve strength and durability. These are advantages which are inherent with the compound system, when it is properly applied. Now, the initial load, or blow, occurs at the beginning of the stroke—the "dead center" —when there is no turning effect, and it is felt throughout the mechanism in pins, bearings and bolts. Obviously, any lessening of its force should bring, in some degree, a lessening also in the need of adjustment and repair. Similar reasoning applies to a reduction of the variation in strain during the stroke.

With the boiler of the compound locomotive, the slower combustion and smaller amount of fuel means less "forcing," a lower fire-box temperature, a reduced range of expansion and contraction of material, and greater durability. There being also less water evaporated, the amount of foreign matter in the boiler will be less, thus decreasing the number of washings required and the time lost while out of service.

Against these advantages in repair and maintenance must be set the care and repair of such additional parts as the compound engine gives the locomotive. These vary in number and character, with different types. It has been fully shown, however, in long service, with some of those to be described, that the cost of repair and maintenance in the compound locomotive is not higher, but equal to, or less than, that of the single-expansion engine, since the added parts are relatively few and simple, the driving mechanism is much the same, and the wear and tear of the boiler are less.

With regard to the tractive power, some compound locomotives exert maximum effort by admitting live steam to the low-pressure cylinder, while others are capable of conversion, simply and quickly, into single-expansion engines, the high-pressure exhaust being opened to the atmosphere and live steam being admitted to the low-pressure cylinder. This gives the engine, in some cases, an increase in power of 25 to 30 per cent. One of the peculiarities of railroad service is that the adhesion varies considerably, while, in the single expansion engine, it is not possible to vary the factor for maximum tractive force. The reserve power of the compound, as noted above, gives this varying factor for critical times.

In general practice, the maximum tractive power should be about 22 per cent. of the adhesive weight, in order to meet all changes in weather and rail conditions without excessive slipping. At times, however, a higher percentage can be used with advantage; as, for instance, in a sharp curve, up grade, at slow speed, where the outer rail is higher than the inner. The wheel flanges then press against the inner rail, thus

increasing the frictional resistance of the engine as well as its adhesion to such an extent that the tractive, or cylinder power can be run up to 30 per cent., or more, of its adhesive weight for temporary use. At such times, the compound locomotive, with its reserve power, will take a train over a grade that would stall a simple engine of equal weight and factor of tractive force.

With the same weights of coal and water carried as in the single expansive engine and with the reduction in the amounts used by the compound locomotive, a corresponding reduction may be made in the number of water tanks and coal-stations along the line, thus giving greater range in selecting stations where good water may be found and lessening the cost of maintenance and supply. Spark-throwing is an evil in railroading against which, with the strong exhaust of the single-expansion engine, there seems to be no adequate safe-guard. Large sums are paid annually as damages by roads on which combustible vegetation and flying sparks combine to produce destructive fires. With the mild exhaust and reduced draught of the compound locomotive, fewer sparks are drawn from its furnace and there is, as well, a greater tendency to retain them in the smoke-box In some tests, the actual weight credited to "sparks" has been shown, for the compound, to be but about 50 per cent. of that from the single-expansion engine. Absolute immunity from the danger noted would be, perhaps, too strong a claim for the compound locomotive; but it is stated that no such fires, owing to it, have yet been reported. On roads where there is much inflammable matter, the protection thus given would seem to be of grave importance On all roads, however, spark-throwing is by no means a negligible factor in the economies of combustion. In the paper by Professor Goss, to which reference has been made previously, he gives, as the result of tests with rates of combustion varying between 64 and 241, values of spark-losses, in per cent. of coal fired, ranging between 4.3 and 15.5; and says further:—

"According to popular judgment, the loss of heat by sparks has always appeared small; while the data show, that, under conditions which are now common, it may represent more than 10 per cent. of the fuel value of coal fired."

ENGINEERING EXPERIENCE.

By G. W. Dickie.

(From Cassier's Magazine, November, 1897.)

Experience, in the writer's opinion, is the formative or moulding effect upon the mind of the thoughts that may pass through it from within, and all the impressions received by it from without, in regard to the work with which our lives are identified.

Memory must be a powerful factor in experience; in fact, the

man of experience is such by virtue of the store of impressions which he has gathered and arranged in his mental storehouse in such order as to be readily available at the moment when their evidence is required to decide his course of action in regard to the subject to which these impressions relate.

When a plan or design for any engineering work is presented to an experienced engineer for his opinion as to its merits, or practicability from an engineering or commercial standpoint, a series of pictures at once present themselves to his mind. These are mental photographs of similar works, or works of the same character with which he has been connected in the past.

Where they succeeded and where they failed are clearly pictured to his mental vision, so that he will be able to readily compare these pictures with the proposed plans, and as the pictures of failures or successes most nearly coincide with the plans before him, so will his opinion be. This is experience, and it is this quality in an engineer that commands the highest price in the engineering market.

But, you will say, engineering is an exact science, or it is every day coming nearer to it, and all problems in engineering are capable ot demonstration, and if the past work of any engineer had been carefully figured out in all its details, these mental impressions in regard to the results of the finished work would, or should, be simply a record of successes.

I do not doubt that engineering is an exact science, but engineers have never found out the exact way to apply this science to the ever-shifting conditions under which they must do their work. An engineer's most careful and exactly figured out designs sometimes surprise him more than other designs under quite as difficult conditions to which he had given little time or thought.

The static laws and dynamic forces in his most carefully planned machines get into most fatal misunderstandings with one another, and he stands puzzled amid the mechanical wreck, without any satisfactory reason furnished by the result to show why this thing, that figured out exactly right, should be so hopelessly wrong. But if he be wise, the impression will not be lost, and will always appear as a bright mental picture whenever his opinion is required on a class of mechanism of which this picture is a type.

Did you ever observe the difference in the appearance of a piece of mechanism that had been designed on scientific principles, with every part figured out to stand the strains that theoretically should come upon them; every journal having just the proper amount of surface for the load; and another piece of mechanism for the same duty, but which had been developed by experience with the working of many predecessors? No scientific reason could be given for the forms into which certain parts had developed, except that they would not work satisfactorily in any other form.

A vessel was built on the Atlantic coast several years ago, and was engined by a scientific man. Every part was evidently planned in accordance with correct principles, so far as that particular part was concerned. The engine was triple expansion; the forward part of the shaft was made the correct size for the high-pressure cylinder; the middle part was made the correct size for the intermediate pressure cylinder, with the high-pressure added, while the after part was made the correct size for the low-pressure cylinder, with the intermediate and high pressure added.

I had a talk with the designer of this strange-looking machine, and he was positive that the general practice of marine engine builders was all wrong in this particular, and on many other points.

But there are particular experiences that men acquire and that have a great effect in shaping their practice. For instance, in designing, say, a pump for high pressures, and large quantities, I might, under certain conditions of working, and with certain kinds of water, employ hard rubber valves in metal cases; while under other conditions of working and kind of water to be handled, I would prefer metal valves.

Yet I could not say in advance just what conditions would determine me to choose either way; for while the conditions might not be such as to give a promise of very great advantage to either the one kind or the other, something else, as for instance, what kind of valve could be most readily procured in the place where the pump was to be operated, might decide the question for me.

I have said something about engineering being an exact science; this is true only in part. The laws that govern bodies in motion and at rest, the expansion of gases, the conservation of heat and energy, are all exact in their operation, and the same conditions will always produce the same results. But the engineer has to apply these laws and forces through materials in the structures and in the machines which he designs, which are ever varying in their qualities of strength and endurance, and which may behave satisfactorily at one time and fail utterly at another, when, to all appearances, the conditions are the same.

"Why," he asked, "should the crank-shaft be made of the same size throughout, when, if the engine is properly designed, the forward part transmits but one-third the work, the middle part two-thirds, and the after part the whole work of the engine?"

Here the want of experience resulted in a failure, because the designer thought that the general practice was the result of lack of knowledge. He could not foresee that his journals and crank pins, being all of different diameters and lengths, and consequently having different velocities, would wear unequally, and that the shaft could not be kept in line.

Two metal surfaces may work together, as a journal and bearing, with perfect results at one time, leading you to believe that you had reached the desired end of your search for a satisfactory

bearing; yet, when you duplicate it under apparently the same conditions, you can get nothing but disappointment, showing that your first work was very near failure, though you did not know it. This is why some experienced engineers never repeat what was thought by those not in their confidence to be a great success.

Recently there were launched at the Union Iron Works, at San Francisco, two vessels from two sets of ways, parallel to each other. Now, two parallel lines are supposed to stretch out indefinitely, but never come together. Why did these two ships, launched on parallel lines, come together so suddenly, when their rudders were set to make them diverge? We have not yet been able to find a reason for it.

Our experience is now against launching two ships at the same time from parallel ways; our experience forbids it being done in that way. Still, some one else might do such a thing and be successful, and thus acquire an experience totally different from ours, and never know how near he came to doing an unsafe thing.

This illustrates what I mean by saying that no man can impart his experience to another, as it is acquired for his own use solely. If we were to be guided by another's experience, progress would be at an end in certain directions.

Men have found that certain things could not be done, because they tried and failed; other men, searching for experience for themselves, will try to do these same things and do them successfully, and thus gather an experience that contradicts that of the others. And this process goes on continually.

What my experience tells me will fail, another's experience tells him will succeed, and yet my own experience must guide me, and not that of another. Experience is a thing of slow growth, for often the first impressions produced by our work have to be modified as certain tendencies on the part of the work develop.

This is especially true of moving mechanism. An engine or machine may make a fine start, and engineering experts may give good reports of it, so that its designer may feel justly proud of the result of his labors. But by and by certain tendencies begin to manifest themselves; workmen are employed nearly every night on it to keep it in condition to run in working hours; still the fatal tendencies keep developing until the machine is broken in constitution and must be abandoned.

This is the end of many a fair start, and alas, how many of the model engines and machines that get conspicuous illustration and description in engineering publications come to just such an end! On the other hand, machines that required careful nursing at the start have developed constitutional strength that enabled them to serve their day and generation with credit.

ABSTRACT OF THE MINUTES OF THE SOCIETY.

REGULAR MEETING, 2nd OF MARCH, 1898.

A regular meeting of the Society was held in its rooms, 1736-9, Monadnock Block, Chicago, on Wednesday evening the 2nd of March, 1898.

President Alfred Noble in the chair, Nelson L. Litten, Secretary. Forty-one members and guests present.

The minutes of the previous meeting were read and approved.

The Secretary reported for the Board of Direction, by announcing the election at its meeting on the 1st inst., of David Sloan, Francis B. Badt, Frederick Sargent, Henry J. Westover, Oscar Sanne, Wm. Kramer, J. G. Giaver, G. H. Hillebrand, David Macdonald, John H. Eustace and George T. Adams, as members. George C. Geraty and Emil K. May, as juniors.

Application for membership was received from Andrew H. Green and referred to the Membership Committee.

The report of the Committee appointed to prepare a memorial on the death of Edwin G. Nourse, was received and read by the Secretary. A motion was made and carried that the report be accepted and placed on the records of the Society and that copies duly prepared be sent to the family of the deceased.

The paper previously announced for the evening on "The Evolution of the American Type of Water Wheel," prepared by Mr. W. W. Tyler, was, in the absence of the writer, read by Mr. T. L. Condron. The paper described the varying stages of progress and detailed the difficulties which were met in the experiments that led up to the efficiency of the present type of wheel. After a short informal discussion the meeting adjourned.

SPECIAL MEETING.—16th MARCH, 1898.

A special (the 380th) meeting of the Society was held in its rooms in the Monadnock Block, Chicago, on Wednesday evening, the 16th of March, 1898.

Second Vice-president A. V. Powell in the chair, and fifty-five members and guests present.

Mr. Dankmar Adler was presented and read his excellent paper on "Mechanical Plants in Large Buildings," touching upon methods of ventilation, lighting, heating, etc. The paper had the close attention of the audience, and was followed by an extended discussion of suggestion and explanation.

The secretary reported for the Board of Direction the election of Andrew H. Green to active membership; the receipt of applications for membership from Wm. A. Wallace and H. R. Safford.

Mr. Edward Hennessey was then introduced and read a paper on "Improved Portland Cement," prepared by Mr. John W. Dickinson, in which reference was made to the improvement in the preparation of raw materials, the necessity of careful grinding and burning to insure effective chemical combination of lime and silica, and advanced methods of mixing. An interesting discussion of the subject followed.

Adjourned.

ENTERTAINMENT—26th MARCH, 1898.

An illustrated lecture on Mexico was given by Mr. William J. Karner, C. E. at the Technical Club rooms, 230 So. Clark street, Saturday evening, March 26th, to the members of the society and their ladies; invitation was also extended to the members of the Technical Club and their ladies. A delightful

evening was spent by a considerable audience in viewing the wonderful scenery of that country and listening to the instructive and interesting descriptions.

At the conclusion a vote of thanks was heartily given the lecturer.

REGULAR MEETING—6th APRIL, 1898.

A regular (the 381st) meeting of the society was held in its rooms in the Monadnock Block on Wednesdsy evening the 6th of April, 1898. Second Vice-president A. V. Powell in the chair, fifty members and guests present.

The minutes of the previous meeting were read and approved. The secretary read a letter from Prof. A. M. Feldman referring to the death of Sir Henry Bessemer and suggesting that the Western Society of Engineers be pioneers to stir up the prominent engineering societies of the United States in a movement to erect an enduring monument, in some shape, to perpetuate the memory of this great man. Mr. Liljencrantz moved that a committee of three members of the society be appointed to draft suitable resolutions and that Mr. Feldman be made chairman of the committee and authorized to select the other members; unanimously carried.

Gen. Wm. Sooy Smith was then presented, and read his paper on "Fire-proof Construction and Prevention of Corrosion." At the conclusion of the reading the Chair stated that, as the second paper of the evening followed closely the line of the first paper, discussion would be withheld until Mr. Abbott finished reading his paper, unless objection was made. Objection not being offered Mr. Abbott proceeded with his paper entitled "Fire-proofing of Warehouses," presenting illustrations enlarged by the stereopticon. The papers were then discussed by Messrs Pond & Pond, Gen. Sooy Smith, Messrs C. L. Strobel, Q. L. Condron, H. P. Boardman, A. S. Coffin and Thos. T. Johnston.

Mr. Condron moved that the subject be held open for discussion at the next regular meeting, May 4th; that in the meantime copies of the papers be furnished members. Mr. Liljencrantz offered as an amendment that copies be sent to architect societies, and that they be invited to take part in the discussion. Mr. Condron accepted the amendment and the motion was carried. Adjourned.

SPECIAL MEETING—20th APRIL, 1898.

A special (the 382d) meeting of the Western Society of Engineers was held on Wednesday evening, the 20th of April, 1898. President Alfred Noble in the chair. Fifty-six members and guests were present. The minutes of the previous meeting were read and approved. "The Topical Discussion upon Electrical, Pneumatic and Mechanical Power Transmission in Manufacturing Establishments" was taken up. Prof. D. C. Jackson of the engineering department of the Wisconsin University opened the discussion by referring to the general availability, convenience and economy of electricity for power purposes. Mr. Eugene B. Clark, electrical engineer of the Illinois Steel Co., discussed the use and desirability of electric power in rolling mills, and cited the following as some of the uses to which it is applied in the Illinois Steel Company's plant.

1. Lighting—both arc and incandescent.
2. Series motor operations, as motors on traveling cranes, electric hoists and conveyors, changing and drawing machines, table rolls, transfer cars, etc.
3. Shunt Motors operated intermittently, driving lathes, shears, pumps, crushers, drills, etc.
4. Shunt Motors—operated continually.
5. Incidental uses.

Interest was added to the paper by a large number of stereopticon views of the features described.

Additional discussion upon the electrical division was had from Messrs. Brinckerhoff and Coster. The pneumatic section was then introduced by Mr.

James F. Lewis of the Rand Drill Co. Facts and figures were presented to show the efficiency of this power in every field of operation. It was claimed that very few situations could be cited where compressed air could not be used advantageously.

Numerous letters from railroad men were read emphasizing the efficiency and economy of using compressed air in connection with railroad workshops. The transfer of mail matter by the use of compressed air in Boston, New York and Philadelphia was also commented upon. Mr. Lewis referred to some experiments with "Liquid Air" which he witnessed in New York City. Mr. C. W. Melcher, of the Ingersoll-Sergeant Drill Co., next presented a paper with a considerable number of views, adding further testimony to the confidence compressed air is establishing as to its fitness in various works. Mr. H. J. Westover, of Sargeant & Lundy, taking up the mechanical question, gave a number of figures of practical tests of the transmission of power direct to machines through several belts, etc. Mr. Robert Ardell, of the Link Belt Machinery Co., presented the American feature of "Manilla Rope Transmission," illustrating his remarks with twelve lantern illustrations.

Mr. Thos. T. Johnston, assistant chief engineer of the Chicago drainage canal, suggested in a brief way the transmission of power by water—the advance recently made in the design and manufacture of water motors. A general discussion followed, and the interest prolonged the meeting to a late hour.

It was announced that the society had leased additional space increasing the size of their rooms about fifty per cent, as the present quarters have become too small to meet the demands and increasing interest in the society.

The secretary reported the election of Mr. Wm. A. Wallace, assistant engineer C. I. & L. Ry. Co., as active member, and Mr. H. R. Safford of the I. C R. R. Co. as junior. Adjourned.

Nelson L. Litten,
Secretary.

LIBRARY NOTES.

The Library Committee wishes to express thanks for donations to the library. Back numbers of periodicals are desirable for exchange and aid in completing valuable volumes for our files.

Since the last issue of the Journal, we have received the following as gifts from the donors named:

Transactions of New England Cotton Ass'n.—Oct. 27-28, 1897.
U. S. Treas. Dept.—Statistical Abstract of the United States, 1897.
Board of R. R. Com'rs of Mass.—29th Annual Report, January, 1898.
B. F. Sturtevant Co.—Mechanical Draft.
American Society of Heating & Ventilating Engineers.—Transactions of, 3d Annual Meeting, January 26–28, 1897.
Sewerage Com'n. of Baltimore, Md., 1897, Report of.
U. S. Treas. Dept.—The Foreign Commerce & Navigation of the U. S. for year ending 30th June, '97.
U. S. Bureau of Foreign Commerce.—Consular Reports, March, 1898. Exports declared January, 1898.
Robert A. Smart, M. E.—The Performance of a Four-cylinder Compound Locomotive.
Deeper Water Ways from the Great Lakes to the Atlantic.—Reports of the Canadian Members of the International Commission.
Proceedings of the 7th Annual Convention of the Ass'n of Railway Superintendents of Bridges and Buildings. Oct. 19, 20, 21, 1897.
Smithsonian Institution.—Proceedings & Trans. of the Nova Scotia Institute of Science. Session 1896–7.
Almon D. Thompson.—6th Annual Report of the Dept. of Public Works, Peoria, Ill.
Cement & Engineering.—The Constitution of Hydraulic Cements.
Chicago Electrical Association.—Standard Diagrams for Uniformity in Electrical Engineering & Patent Office Drawings, February, 1898.
Institution of Civil Engineers of Ireland.—Transactions. 63d Session, to May, 1897.
Chief of Engineers, U. S. A.—Monograph upon Reservoirs and their Effects upon Floods of the Mississippi River, by James A. Sheldon, Asst. Eng'r.
L. G. Carpenter.—10th Annual Report Agricultural Experiment Station of Colorado, for 1897.
Mass. Institute of Technology.—In Memory of Francis Amasa Walker, President of the Institute.
Annual Catalogue, 1897–8.
Annual Report of President and Treasurer, December, 1897.

PERIODICALS.

New Exchanges on file in the Library:

The Electrical Review, London, England.
Railroad Men, New York City.
Thonindustrie-Zeitung, Berlin, Germany.

The library and reading rooms are open from 9 A. M. to 5 P. M., on week days, except Saturday, until noon.

Journal of the
Western Society of Engineers.

The Society, as a body, is not responsible for the statements and opinions advocated in its publications.

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XXXIV

"A TOPICAL DISCUSSION UPON ELECTRICAL, PNEUMATIC AND MECHANICAL POWER TRANSMISSION IN MANUFACTURING ESTABLISHMENTS."

Held April 20, 1898, before the Western Society of Engineers.

Prof. D. C. Jackson: I have no set speech for this evening. This society has heard from me within eighteen months upon this subject, and as the paper I read at that time was practically repeated at a meeting of the American Society of Mechanical Engineers, it is doubtless more or less well known to you from the journals of both societies. In the way of opening the discussion, I will repeat two or three of the remarks made in my former paper. It will give a foundation for discussion and give the men who have had large experience with compressed air and with ropes and shafts and belts a foundation for argument—give them a hook upon which to hang their facts.

The question of power transmission in manufacturing establishments may be stated thus: What can be installed to do the work in manufacturing establishments in transmitting power from the prime mover to the machines, with (1) the least cost for the plant and with (2) assurance of the least operating costs and the best satisfaction in operation?

We all must admit that for general purposes electric transmission is likely to cost materially more than shafts and belts, or shafts and ropes. While I have had no experience with compressed air, I am inclined to the belief that pneumatic plant installed for general transmission purposes would be much more costly than electric plant. On the other hand, for many special purposes the first cost of electricity is no greater than the first cost of other transmitting agents which will do the work. There are many places in which shafts and belts, or shafts and ropes, cannot serve satisfactorily. In the latter places electricity has often displaced other means of transmission; and we now have

numerous manufacturing establishments in this country, which turn out a heavy or bulky product, in each of which considerably over one thousand horse power of electric motors are in use driving general machinery. There are some plants which individually use over two thousand horse power in electric motors. In these cases the electrical machines have almost invariably replaced older methods of transmission with success and advantage, as is shown by the fact that electrical transmission is being increased in magnitude in almost every one of the plants referred to.

Such favoring of electrical machinery is particularly evident in iron and steel plants, where electrical transmission has shown its advantages particularly on account of the enormous weight, and in some cases the great bulk of the product that is gotten out which narrowly limits the possible positions of the operating machines. In such classes of work electrical transmission gives the greatest advantages, because an electric motor can be placed anywhere that it is desirable to place it alongside of its machine which it drives, and the transmitting wire may be twisted around corners or poked through holes without loss of efficiency and without added expense. In steel works we have had much transmitting of power from boiler plants directly to engines located all over extended works, but that is not as a rule as economical as electricity, as is shown by the rapid extension of electric power plants in existing steel works.

As a rule, the already established general manufacturing establishment, that is the manufacturing establishment for ordinary product (product which is neither remarkably bulky nor remarkably heavy or which does not require a special degree of cleanliness), does not find sufficient advantage at the present moment to make it clear that the old transmitting agents should be thrown out and new placed in the works. The extra capitalization required for such a change undoubtedly makes a pretty heavy load in many cases; yet there are quite a number of manufacturing establishments of the general type that would find it greatly to their advantage to make the change.

In regard to new establishments, I summed the matter up in my earlier papers, and will quote briefly from them: "For plants using not less than one hundred horse power the electrical transmission is so much more satisfactory and economical that it is a misfortune for a new manufacturing plant, except under very exceptional conditions, to be constructed with any type of transmission except the electric." This refers to the transmission of power for general purposes about the establishments. There are many special classes of work that can be carried on advantageously by compressed air, but the compressor can be driven from the electrical system.

As a summary of the whole matter, I will quote again from the earlier papers:

"1. In constructing new manufacturing plants, the extra first cost of a complete system of electrical transmission for the works is negligible (except under exceptional circumstances), compared with the annual savings effected by its means when its advantages are properly utilized.

"2. In certain industries the advantages of electrical transmission outweigh the first cost of making a change from mechanical to electrical transmission in established plants, while in many plants where this condition would not commonly exist the arrangement of buildings or the growth of the plant is frequently of a character with reference to the prime power plant which places electrical transmission upon an advantageous footing, either as an auxiliary to the main transmission or as a rival to the existing mechanical transmission."

You will notice the statement in this quotation, "when the advantages of electrical transmission are properly utilized." Therein lies a very important matter. Different industries require entirely different arrangements of plant, as has been shown by experience, and the arrangement must be given the most careful attention to attain the best results.

An electrical power plant which is put into a manufacturing establishment should be installed for the purpose of operating all classes of apparatus which are intended to be operated by electricity. This, of course, is not intended to include call bells and other playthings, but it should include all the important matters. In other words, unless the plant is exceedingly large, the same installation of machinery should operate motors for driving machinery, operate electric lamps for lighting, and operate other appliances which may be useful. This is very readily brought about by the use of either continuous currents, or alternating currents. I am inclined to believe that the alternating current motor has so clearly shown its advantages as to place it on a very important footing in this work. I was inclined to doubt that it had proven its peculiar advantages eighteen months ago, but it has had an opportunity to prove them since then, and it certainly should be placed upon an even footing, possibly a little better than an even footing for certain classes of work, with the continuous current motor.

It can be taken for a fully established fact that either continuous or alternating current electrical machinery is as reliable as any class of machinery that is now built. The experience in severe service which was met by electric machinery on electric railways, and which was satisfactorily met, has brought the construction of electrical machinery for all purposes to a degree of perfection that makes it as reliable (as said above) as any type of machinery that is built.

ELECTRIC POWER IN ROLLING MILLS.

Mr. Eugene B. Clark, of the Illinois Steel Company, read the following:

The conditions existing in a large rolling mill are particularly advantageous to the use of electric power for operating many of the auxiliary machines which are scattered through such a plant. The large area, compared with the average manufacturing plant, which is covered by a steel mill, necessitates either a large number of small complete steam units or else a large amount of piping. The economy of either method is so low as to be prohibitive in many cases, consequently we must either bring the outlying machines into a small radius at the sacrifice of convenience and economy of operation, or we must adopt some cheap method of power transmission. Both pneumatic and hydraulic transmission has each its own particular field in which it possesses superior advantages, but when the field of each has been covered there still remain a large number of places to which power can be conveyed by electric means far more cheaply and far more conveniently than by any other method. Of course, the question of economy is the prime consideration, but the word "economy" to the manager of a rolling mill has a somewhat broader meaning than it does to the average station manager. The question of convenience of operating a mill is oftentimes so important that an apparently wasteful method is frequently preferable to one which is more economical from the steam producer's standpoint. A highly efficient motor may be, and generally is, much inferior to one whose mechanical excellence and high insulation reduces its liability to break down to a minimum. Of course, what we want is a combination of all these qualities, but it is not always possible to obtain it.

The uses to which electric power is put in a steel plant are numerous and diversified. Among them may be mentioned:

(1) Lighting, both arc and incandescent. Much of the arc lighting is preferably of the series kind, by reason of the considerable territory to be covered, and as yet the open arc lamp has not been displaced to any considerable extent for series work, though the enclosed lamp is making inroads upon its field. For inside lighting, however, meaning the lighting of the interior of the mills, constant potential enclosed lamps possess advantages, which are even more marked than in many of the stores and halls where they have superseded the open arc. The trimming of an arc lamp in a mill during a week day nearly always seriously interferes with the operation of a part of the work being done there, so the installation of long burning enclosed lamps saves more money than is represented by the decreased cost of carbons, the decreased labor of trimming, the decreased repairs and attendance on series arc machines, and the decreased fuel consumption attendant upon running small units instead of large ones, as usual

in such comparatively small lighting plants. Incandescent lighting may be of two kinds also with advantage. Such as is necessarily far distant from the source of generation should be alternating, from considerations of economy of transmission, while such as is close at hand may be direct, operated directly from the constant potential mains.

(2) Series motor operation: This covers the use of motors on traveling cranes, electric hoists and conveyors, charging and drawing machines, table rolls, transfer cars, etc. All such motors are operated intermittently, and therefore make demands upon the steam plant only at the times and in the proportions that work is demanded of the motor. This means, of course, that no losses occur in the transmission lines except when power is being used.

(3) Shunt motors operated intermittently. This covers the use of electric power to drive lathes, shears, pumps, fans, crushers, drills, punches, etc. Such motors operate rather more steadily than series motors, but still their demands upon the generator are decidedly uneven.

(4) Shunt motors operated continually. There are always some such motors distributed through a large plant to operate grinding machines, crushers, pumps, fans and similar devices. Some of these operate all the time, some only during the week days, some at night, and some in the day and so on.

(5) Incidental uses. By these may be covered the use of electric current in lifting magnets, signals, testing devices, etc. The power used in this way is considerable.

Upon a careful consideration of the relative value of each of the above classes of loads depends the intelligent design and location of the generating plant. For rolling mill work at present, direct-current apparatus seems much better suited than alternating, on account of the difficulty of properly controlling alternating current motors under such conditions as exist on travelling cranes and similar machines operated each by a number of motors. However, it is the controlling device which gives the trouble with direct-current apparatus now, and not the motor, if it is a good one, and if an entirely new plant were being built, it would be a question to be very carefully investigated whether the advantages of transmission by an alternating system would warrant its installation as against a direct-current system. The most suitable voltage is between 220 and 250, the former being preferable for smaller plants, and the latter for larger ones. The units should be chosen of as large a size as is compatible with a sufficient allowance for reserve power, without too high an investment for machinery. The load curve on the generating plant should be carefully plotted from readings on such motors as are already installed (if the question is one of increase), and from careful consideration of the probable character of the increase of load. A study of the probable load curve gives opportunity for intelligent selection of units. The accompanying figures

show such a load curve plotted from the conditions existing at the south works of the Illinois Steel Co. Three figures are represented.

Fig. 377 shows the actual variation of the load on our present power station, each small horizontal line being the plotted average of ninety readings, extending over a period of fifteen minutes

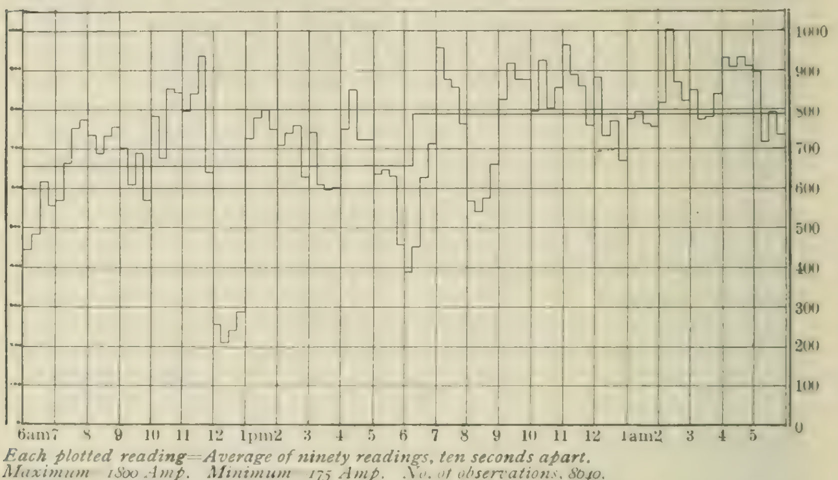


FIG. 377. CHART SHOWING ACTUAL LOAD ON PRESENT POWER STATION ILLINOIS STEEL CO., SOUTH WORKS, MAY 2, 1898.

with ten seconds intervals. The form of this diagram will vary from day to day, the one given being a representative day's run. A number of such diagrams superimposed upon each other will give an average line such as shown in the next figure.

Fig. 378. The line marked "Average Load Without Battery," is a representave curve of the average fluctuation of load during twenty-four hours under present conditions. Beginning at 6 A. M. the load is about 400 amperes, from which it increases rapidly to about 700 at 7 o'clock. Then just before noon it runs up about 100 or 200 amperes, but drops off to about 400 again between noon and 1 P. M. It runs up a little before 6 P. M., more or less, according to how dark it is, and then drops off again, somewhat, after 6. This cycle is repeated again during the night, the load being a little heavier, however, on account of the lights. The sharp peaks on Fig. 378 show how the load actually varies. Of course, if a high peak should occur between 12 and 1 o'clock, due to a heat in the open hearth, or some similar cause, this Fig. would be changed somewhat. The straight line marked "Average Load With Battery," is the line to which the load curve would closely approximate if an accumulator plant were installed. This Fig. was plotted upon the average of a great number of readings, taken under average conditions.

Three distinct kinds of fluctuations will be noted, viz: (1) those occurring rapidly (about one per second); (2) those having a periodicity of about 30 minutes, and (3) those occurring every six hours. Increasing the motor installation (along the same lines as we now operate) decreases the relative value of the first class of fluctuations, does not affect much the second class, and increases the relative value of the third class. That is,

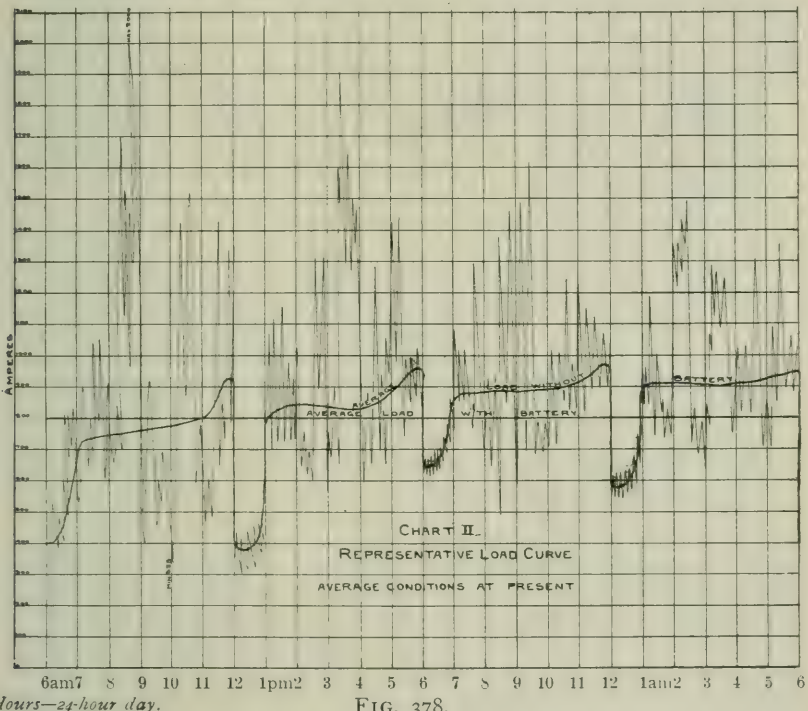


FIG. 378.

the average load without batteries will become more uneven as we increase.

Fig. 379. This is a small portion of the actual load curve, plotted from 120 consecutive readings, five seconds apart, taken under average conditions.

From consideration of these charts it appears that if we could smooth off the peaks of this load curve we could operate double our present installation of motors with one unit of about 1600 amperes capacity, while if it is as represented it would require the operation of two units. Under such conditions the installation of an accumulator plant seems advisable. Then the motor load and the light load could be placed each upon its own circuits, and by compounding the battery with a differential wound booster the load and the voltage

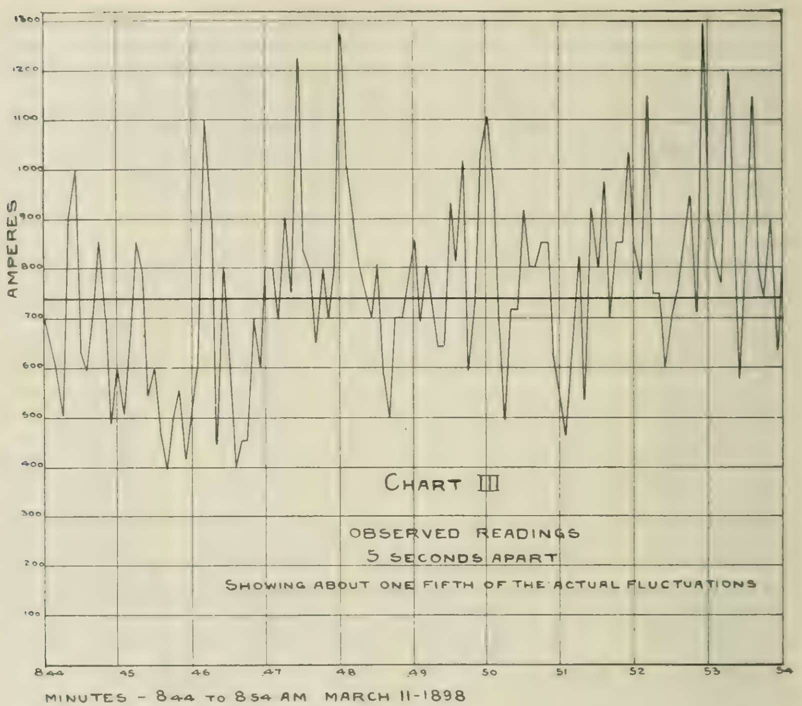


FIG. 379.

on the light circuits could be kept almost constant, all automatically. For such a use, i. e., as a regulator, the storage battery is exceedingly well adapted; and when used in this way the loss in the battery is a very small amount. The economy of operating one unit instead of two is apparent, and in this case other advantages accrue to this plan, viz., to enable the operation of at least the most important part of the load in case of an accidental disablement of the steam plant for a short time; and to enable shutting down the steam plant on Sundays and holidays during the periods of light loads.

In the views of motor-driven apparatus which follow, one fact will become apparent, viz.: that though it is possible to have an artistic and pleasing central station, equipped with highly economical machinery, it is hardly possible to install the motors and other current consuming devices in the mills proper in a manner which will not appear rough and careless. For even if the wiring is put in with great care at the start, as it seldom is by reason of lack of time, it will not be in service long before some hurried changes will leave it in bad shape. And then, too, appearances are not worth the labor to keep them up, in a rolling mill.

Mr. Clark then showed some views illustrating the application

of electricity as a motive power at the Illinois Steel Company's plant at South Chicago, accompanying each view with explanation of particulars.

Mr. Maurice Coster. Mr. President: I did not come to say anything and do not know that I can add very much to Mr. Clark's very excellent paper.

About eighteen months ago, when we had a discussion here, I listened with great pleasure to Prof. Jackson's very interesting paper. I took a strong stand at that time in favor of alternating current apparatus for power purposes. The developments of the last eighteen months have proven conclusively that the position taken by the Westinghouse Electric & Manufacturing Company, in recommending alternating current apparatus for the transmission of power, has been the correct one, inasmuch as fully eighty per cent. of the power plants installed in this vicinity within the last year are operated by polyphase apparatus. There must be a great deal in the alternating current system, when we take into account that such conservative people as those who dictate the business policy of the large packing houses at the Union Stock Yards, have adopted induction motors at an increased cost, in preference to the direct current motors.

It is a great advantage to have a motor without a brush or commutator, which can be reversed just as readily as a direct current motor, a motor which has a maximum average efficiency and requires a minimum amount of attention and repairs. These advantages are embodied in the alternating current motor.

It should be borne in mind that a direct current cannot be practically obtained from a generator without the use of a commutator to rectify the alternating current. Why then should we make use of this expensive and cumbersome commutator, which requires so much attention, when we can obtain better results by using the original alternating current?

When the question arises whether hydraulics, pneumatics or electricity should be employed as a means for transmission of power, it behooves the engineer to carefully investigate the subject before arriving at a conclusion. Undoubtedly each of these three agencies have their place

From some of the illustrations of machinery employed in rolling mills, shown by Mr. Clark, we note that hydraulics and electricity are used side by side. Where there is required an absolute, steady and slow moving action, there is, in my mind, nothing to take the place of hydraulics. For small units, where the distance of transmission is short, air motors have been employed with a considerable degree of success. Electricity, however, is the most flexible agent of the three; we can turn corners with it, regardless of the sharpness of the angles; nor need we fear that it will freeze.

Some engineers have recommended the substitution of electricity in places where it would not give the desired economy.

I hope that I shall never be placed in the position of one of my competitors, who went to a prominent steel manufacturer in Pittsburg, some years ago, and said, "Now, you do not want these little steam locomotives in your yards; you should put up trolley wires and use electric locomotives." I was fortunate enough to have the confidence of this steel manufacturer and he said to me, "Just think of it, Mr. Coster, Mr. So-and-so recommended that I should take all my wheel-barrows"—of course he exaggerated—"and equip them electrically; that I should discharge my dollar and a quarter laborers and hire two dollar and fifty cent electricians to operate the wheelbarrows."

Recommendations of this kind have retarded the introduction of electricity. We are glad to note that our engineers are becoming more liberal, and that they appreciate that sometimes the most economical arrangement can be made by using a combination of electricity, hydraulics and pneumatics.

Mr. Johnston: One question was raised by Mr. Clark which I would like to ask more particularly about, and that is as to the application of the storage battery—as to equalizing quickly fluctuating loads.

Prof. Jackson: The storage battery serves excellently as an equalizer of fluctuating loads; but the question is, what does it cost, and that is what we have never yet been able to fully settle.

Mr. Clark: Do you mean the cost of the battery, or cost in what way?

Prof. Jackson: My previous remark referred to the battery cost in lost power, interest, maintenance and depreciation all told; that is, the total annual cost of operating the battery. We are yet rather in the dark in regard to the total annual cost which the use of the battery will entail.

Mr. Clark: Undoubtedly that is a special case to be considered for every individual installation. The use of storage batteries is advocated under two different conditions, that condition which obtains with the street railway plants and with other plants having a fluctuating load, where it is used as a regulator; also the other condition which exists with a lighting load, such as occurs in very large illuminating companies, where it is used as an accumulator of energy. I believe the Brooklyn Edison Company, of New York, has a number of storage batteries in use, and the Chicago Edison Company is installing a large battery at their Adams street distributing station which possesses the functions of an accumulator, and the railway plants, of which there are three, have been installed in Pittsburg in a year, those batteries have the function first mentioned, that of a regulator; in that case it is used with a booster. At the Buffalo Power Company, or some street railway company in Buffalo, the name of which I have forgotten, they use one for that purpose, being put in, many of them, as regulators and also a number of them for the purpose of accumulators in rubbing off the high peaks of the load.

Mr. H. M. Brinckerhoff: I am not prepared to make any remarks on this subject, it is a little out of my line, but as we can all contribute by making this an experience meeting, I will say in regard to a remark that I heard Prof. Jackson make not very long ago, that it took twenty hours of repairs to keep a motor running the remaining four hours out of the twenty-four. I have had occasion to notice the operation under rather heavy work of some rotary transfers, that is to say, units of 500 volts, motors driven from railway circuits direct, coupled to lighting machines, and in this city there are at present running three of those machines, supplying stations with lights, in each case running day and night, running six, eight and twelve months without stopping, unless in case of short circuit line or something of that sort. One motor generator that I refer to particularly we had in the station of the Metropolitan for lighting, when it was used as a terminus on Franklin street, and the motor had to carry an overload for eight hours a day, and it ran for eight months, and during that time only stopped twice for about two or three minutes, showing the reliability that the apparatus has now attained.

COMPRESSED AIR AS A POWER.

By James F. Lewis, Mem. W. S. E.

The subject of compressed air and its uses offers a wide field of investigation. Compressed air is fast becoming an efficient agent for transmission of power. It is not a new power by any means, as we find experiments in compressing air were made more than a century before Christ, and its application to industrial purposes dates back to the last century, but its success as a mechanical power must be credited to the modern engineer of this day. In his hands it has become a powerful, efficient and most interesting agent.

It was first applied by Cubitt and Brunell in 1851–4 to the sinking of bridge caissons. The next engineering work where compressed air was used to any extent successfully was in boring the Mt. Cenis tunnel.

In America, its first use to any great extent was by Mr. Walter Shanley in driving the Hoosac Tunnel, from 1868 to 1874, where it proved very successful in the saving in cost of construction and time of completing the work. From this time on, the use of compressed air increased very rapidly for underground work—tunneling and mining.

It was first adopted in the iron and copper mines of Lake Superior in about 1876, since which time, up to 1897, there has been mined with compressed air 102,293,757 tons of iron ore, gradually increasing each year from 1,025,129 tons in 1877 to 10,596,559 tons in 1896—an average output of 4,871,131 tons per

year. From the year 1870 to 1876 inclusive the output of ore was 6,591,789 tons, or an average of 941,684 tons per year. The number of pounds of copper mined from 1880 to 1897 in Lake Superior is 1,467,313,651. From this statement you can get some idea of what compressed air has accomplished during the last twenty years, taking into consideratian that this is only one of the mining districts of the United States.

The application of compressed air for mechanical purposes was first started in Paris by Victor Popp, in 1879, consisting of two small compressors and two steam engines of 6 horse power each, and has now increased to 24,000 horse power for mechanical purposes.

In 1892 they compressed 6,887 millions of cubic feet of air. They have a system of 105 miles of compressed air pipe laid under the street, of which 41 miles is used for pneumatic clock service and about 64 miles for the transmission of power for other purposes.

The applications of compressed air for power purposes are very numerous and new work is found for it continually. There is, of course, great diversity of opinion and practice among engineers as to the means of transmitting power, either by steam, electricity, belt, wire rope or compressed air. Air, perhaps, is the only one that is in every case possible. It would be hard to find an engineering project in which air would not fit the conditions as a power.

Very little progress was made in the use of air for mechanical purposes, except in a very crude way, until the past five years, since which time great progress has been made. In fact, it is fast becoming universal for use in machine shops, boiler shops, foundries, railway shops, bicycle shops and also for deep well pumping.

There was much skepticism as to its economy or efficiency for mechanical purposes, but a great change of opinion has and is taking place among many of our most thoughtful mechanical engineers. They are fast becoming converted in favor of compressed air. They find no end to its uses, after it is once introduced into the shop or foundry. The advantages of it as a motive power in shops are numerous. It is easy to handle, it is clean and neat, it is always ready to do its work the moment the throttle is opened; it can be carried from one end of the shop or yard without loss, if properly piped.

The question is often asked, "Is compressed air economical?" We answer, yes, if an economical plant is installed; but a better answer is made by the railways, as no class of mechanics or business men study economy so closely as railway men, and we point to what they are doing with compressed air.

Mr. J. H. McConnell, superintendent of motive power of the Union Pacific Railroad, says: "The many savings through the use of air in the shops of the Union Pacific System aggregate $10,000 per year in labor alone."

Similar statements to the above may be made of the Chicago & Northwestern Railway; Chicago, Rock Island & Pacific; Michigan Central; Detroit, Lansing & Northern; Grand Trunk; Great Northern; St. Paul & Duluth; Pennsylvania System; Cleveland, Cincinnati, Chicago & St. Louis; Lake Shore & Michigan Southern; Northern Pacific; Missouri, Kansas & Texas; Missouri Pacific; Pullman Palace Car Co., and many other railways who are using air extensively.

Edwin S. Cramp, superintending engineer of the Wm. Cramp & Sons Ship & Engine Building Co , Philadelphia, writes as follows:

"We are using the compressor for the purpose of riveting, drilling and reaming, caulking ship and boiler work, blowing fires for rivet heating, cleaning castings, running punching and shearing machines that were formerly driven by steam, and we feel sure that this extended use of compressed air has resulted in an increased efficiency in the performance of our work and that it is the greatest money-saving machine ever adopted in our yards."

Mr. Wm. Renshaw, superintendent of machinery for the Illinois Central Railway Co., says:

"We are at present using compressed air for the following purposes: Elevating sand at engine sand house, elevating oil at oil house, hoisting heavy castings and parts at machine tools, etc., forcing couplings on air hose, operating cylinder boring bar, operating valve facing machine, filling cylinders of hydraulic presses, removing and applying driving tires, testing water pumps after repairs, drilling with motor, tapping with motor, reaming with motor, cleaning boilers, cleaning machinery, punching jacket rivet holes, taking old paint off tin roofs, rolling and beading flues, chipping, cutting, caulking, small bulldozer, elevating water from deep wells, testing air and driver brakes, elevators in store house, operating letter presses, cutting out stay bolt stubs, jacking up cars and trucks, cleaning interior of coaches, cleaning upholstered work, burning paint off coaches, painting cars, sand blast ends of cars, gasoline heater, cutting off stay bolts, screwing in stay bolts, rivet forges, one blacksmith forge, pressing in driving box brasses, operating flange clamp, swedging flues.

"This is the list up to date, but we are finding further use for compressed air every day, and we could not afford to be without it.

"I consider it the best means of transmitting power in and about shops: First. On account of the many uses to which it is adapted and the simple appliances needed in connection with its use.

"Second. With but few exceptions in the above list, steam and electricity could not perform the work without more complicated apparatus, and in a great many instances, air alone is applicable.

"Third. The appliances used and the pipe line are easily kept in repair by our own shop men.

"Fourth. There is no element of danger and the apparatus requires no skilled mechanic to handle same, and it is safe in places where steam or electricity might be objectionable.

"Fifth. It can be carried greater distances without loss than steam, and taking into consideration cost of plant, cost of maintenance, skilled help required, etc., it can be produced for less money than electricity.

"As regards saving made over old methods, would say, taking into consideration all things, that an average all round saving of 25 to 30 per cent could easily be realized. Take, for instance, the saving effected by use of air hoists alone, which, though hard to figure, will assume large proportions when the amount of labor they take the place of is taken into consideration.

"We figure a saving of 60 per cent in burning paint off passenger cars, and 50 per cent in painting freight cars and passenger trucks."

Mr. Geo. D. Brooke, M. M., of the St. P. & Duluth Ry., says: "We are rapidly increasing the use of air. It is giving perfect satisfaction and will soon pay for itself in the item of saving in laboring help independent of shortening the time of doing work."

Mr. E. M. Herr, superintendent motive power of the Northern Pacific Railway, says: "Compressed air is advantageous about a railroad shop for another reason, in this it differs from electricity and has an advantage over it, that is, that when the storage is not being drawn upon, the plant can be shut down absolutely, and still the reservoir with the power is at hand at all times for use. This is of great advantage in a place where but a small amount of compressed air is used and used occasionally. For instance, at night it might be very advantageous to have compressed air at hand for use at intervals, when a compresser that would probably work an hour or an hour and a half at night, would compress all the air that was necessary. This being stored in the reservoirs can be drawn upon and the compressor would automatically shut down when the desired pressure was obtained."

Mr. F. L. Wanklyn, formerly M. M. of the Grand Trunk Railway system says: "The uses to be found for compressed air seem to be inexhaustible as far as a machine shop is concerned, as hardly a day passes without some suggestion being made for a new and advantageous application of this handy and expeditious system of transmitting power."

About two and a half years ago the A., T. & S. F. Ry. installed a duplex 20x48 air compressor in their shops at Topeka, where they have about five miles of air pipe running through their shops and yards. This compressor gives them about 2,000 cubic feet of air per minute. Since that time they have installed nineteen compressors along the lines of their different railways until they are now using between 14,000 and 15,000 cubic feet of free air per minute.

There is only time in this paper to give you a few items show-

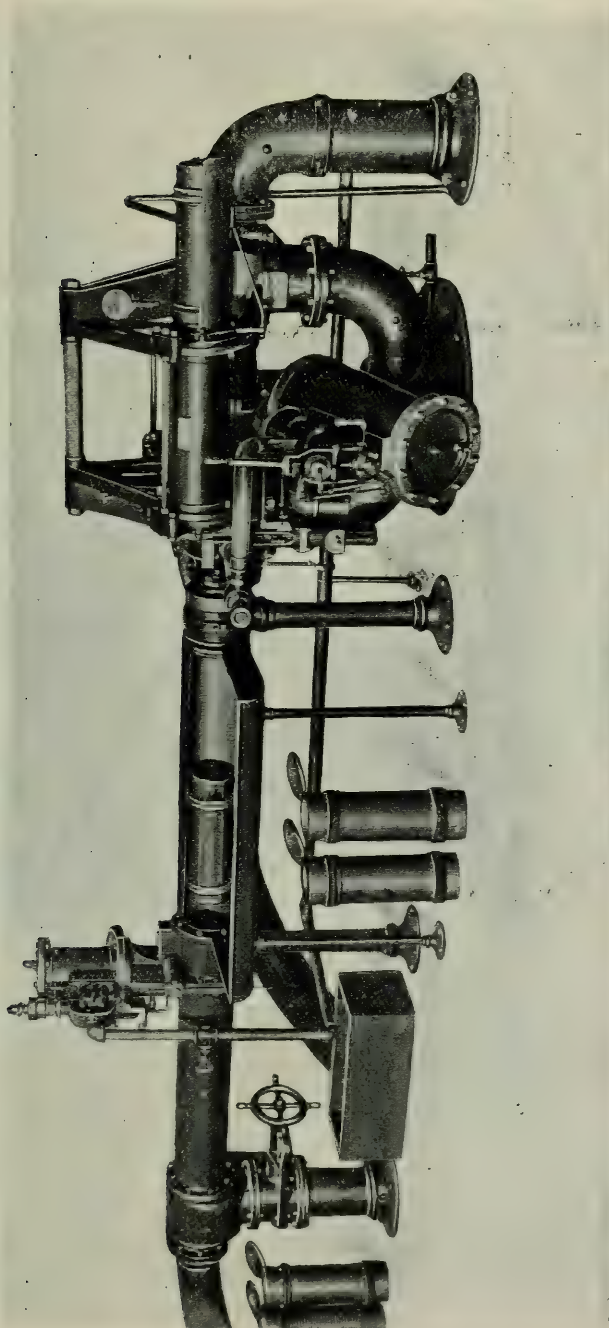


FIG. 380. SENDING APPARATUS AND OPEN RECEIVER, PRODUCE EXCHANGE LINE, MAIN POST OFFICE, NEW YORK CITY.

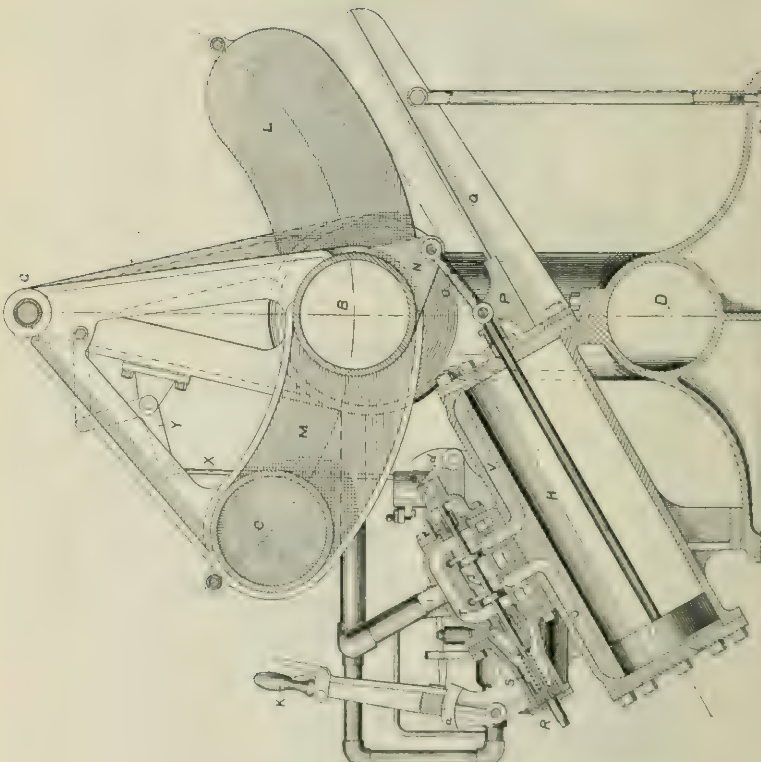


FIG. 381. CROSS-SECTION OF SENDING APPARATUS.

ing the saving in the use of compressed air over old methods. With the ten-foot reach stationary riveting machine they drive 2,000 rivets per day of ten hours with three laborers at a total cost of $4.75 per day for labor. By hand labor three men cost $7 per day and could drive only 200 rivets. The truck riveters, (one machine operated by two laborers) the total cost $3 per day, drive 3,000 rivets in a day of ten hours, while with hand labor three men that cost $6 a day could only drive 175 rivets. The stay bolt breaker will make an average saving of $8 a day; the tank riveter will make an average saving of $10 a day; the mud ring riveter will make a saving of from $12 to $15 per day; not only does it make a great saving, but insures every rivet hole being entirely filled and gives tight work. The stay bolt cutter will do the work of fifteen men, easily cutting off 1,500 bolts an hour. The rotary tapping and drilling machine will do the work of four men. The rotary grinder saves the work of six men. Rotary saw for sawing car roofs saves the work of four men. Rail saw saves the work of two men. Rail drill saves the work of two men. Device for operating transfer tables saves $6 per day. Device for shearing bolts saves the labor of two men. Thirty hoists in shop saves the labor of ten men at $1.50 per day. Device for loading and unloading oil at store house saves $6 per day. Jack for pulling down car draft sills saves $10 per day. Device for fitting up hose couplings saves $15 per day. Pneumatic painting machine, one man does the work of ten using a hand brush, and does the work much better than it can possibly be done by hand with a brush, for the reason that the air seems to strike the wood before the paint, therefore blowing all the dust and dirt out of the cracks and putting the paint where it belongs without any waste of paint whatever. The saving of paint in using compressed air is one gallon to each car over hand brush. Machine for tearing down old car roofs saves $8 per day. Air jacks for raising and lowering freight cars take one man three minutes where previously it took two men ten minutes. Cleaning a car by air saves 10 per cent in time and thoroughly cleans the car, which could not be done by hand. White-washing machine, where it took ten men five days it now takes four men one day and gives a 75 per cent better job. Shifter for switching cars in shop yard saves $50 per week. Blowing out engines with air saves a cord of wood besides the inconvenience and delay, as the men cannot work around the hot engine to advantage.

The Chicago Drainage Canal was a great educator in use of compressed air for open work. Figures prove that compressed air was at least 20 per cent. cheaper than the use of steam for the the same work, and in many cases the saving was 30 per cent. over the same work with steam. Compressed air as a power has certainly proven itself worthy of consideration, and it must be admitted that it is economical and practical in most every engineering problem.

One of the new features for the use of compressed air is the Batcheller pneumatic tube system for the transfer of mail from depots to main postoffices, and from main postoffices to sub-postoffices. This system is working most successfully in Boston, New York and Philadelphia. "The tubes are of cast iron made in 12-foot lengths with bells cast from one end. They resemble ordinary water pipe, but are somewhat thicker and made of a better quality of iron. Short bends in the tubes are made of brass from seamless tubing bent to a uniform radius of twelve times the diameter of the tube, or eight feet for an 8-inch tube. The sending apparatus or transmitter consists of two sections of the tube supported in a swinging frame so arranged that either section can be brought into line with the main tube in which a current of air is constantly flowing. One of these tube sections maintains the continuity of the main tube while the other is swung to one side to receive a carrier. In dispatching, a carrier is placed in an iron trough and then pushed into the open tube section. The frame carrying the two tube sections is then swung until the section containing the carrier is brought in line with the main tube, when the carrier is swept along with the current of air. An air moter consisting of a cylinder and piston furnishes the power to swing the frame, the operator having simply to move a valve by pulling a lever. The tubes now in use are 6 and 8-inch. The carriers which contain the mail during transit through the tube are thin steel cylinders, closed at the front end by convex disc of the same material, carrying a buffer of felt leather. The rear end is closed by hinged lid secured by lock. The shell of the carrier is 24 inches long and 10 inches in diameter. It is surrounded by two bearings of woven cotton fabric, specially prepared and clamped between metal rings. A carrier will run from 1000 to 2000 miles without having these rings renewed. An empty carrier weighs about thirteen pounds, and when filled with mail matter twenty-five or thirty pounds. These carriers will hold about 600 ordinary letters. The time of transit between the main postoffice and Union Station, Boston, is about ninety seconds, and the distance is about 4,500 feet, so that the average speed is fifty feet per second, or thirty-five miles an hour. The air compressors compress about 1,200 cubic feet of free air per minute, to a pressure of six pounds per square inch. This requires the expenditure of about fifty-horse power. The compressor pumps air directly into the outgoing tube."

When the air reaches Union Station the pressure has fallen to about 3½ pounds. It flows back to the postoffice through the return tube and is discharged in a tank in the engine room with the pressure down to atmosphere. The compressor draws it supply from the tank so the same air is continually circulated around the circuit and the loss is made up by taking in from the atmosphere through an opening in the tank. The system is kept in almost constant operation 24 hours a day, and 6 days in the week, and

during the busy hours the carriers are sent frequently under ten second headway. If each carrier contains 600 letters and 6 carriers are dispatched in each direction every minute we have 7,200 per minute dispatched or 432,000 per hour.

It was my privilege recently, while in New York, to visit the works of Mr. Chas. E. Tripler, who has been working for a long time on an invention for liquefying air. The honor of pouring air in a visible liquid stream from one vessel to another and making experiments with it belongs to Prof. James Dewar, of the Royal Institute, London. But recent discoveries have been made for making liquid air much cheaper, by Chas. E. Tripler in New York and at the same time by Prof. Lind in Germany. Prof. Lind's method is an air pump of 5 H. P., condensing air to a pressure of 200 atmosphere. This air passes down a spiral tube and is let out in a chamber causing great cold, then it rises and passes on the outside of a spiral tube, bathing it and thus cooling the new air that has been pumped into the tube to take its place. This cooled air follows into the chamber, expands and again lowers its temperature, then passes on up around the same spiral tube, but as its temperature has become much lower the new air in the tube is still further refrigerated. This circulating process goes on until the new air pumped into the tube reaches the expansion chamber at a temperature of 273 degrees C. below zero when it drops into the chamber in the form of a liquid. Thus the air steadily cooled is made to refrigerate the newly pumped air more and more until the necessary degree of cold is obtained. Mr. Tripler's invention is very similar. His plant consists of a triple air compressor, a cooler and a liquefier. The compressor is of the ordinary form, having 3 cylinders upon one piston shaft working in a line. The first gives 60 pounds pressure, the second raises it to 750 pounds and the third brings the air up to 2,000 pounds per square inch. After each compression the air flows through jacketed pipes where it is cooled by city water. This work requires about 40 H. P. After the third compression the air flows through an apparatus which disposes of some of its impurities and it passes on to the liquefier. It is this part of the apparatus which constitutes Mr. Tripler's special invention. By means of a peculiarly constructed valve whose details are not made public a portion of the compressed air is allowed to expand into a tube surrounding the tube through which the remaining air is flowing. This expanded air absorbs a large amount of heat from the air still under compression in the inner tube. The contents of the inner tube are thus cooled. In this way the air is brought below the temperature of liquefication and its pressure is very much reduced, so that upon opening the valve at the bottom of the apparatus a stream of liquid air is received, flowing out with scarcely more force than the water from our ordinary city service pipe; thus the liquefication of the air is accomplished by the self intensification of cold produced by the expansion of a

portion of the compressed and cooled air without employing any other substance to bring about this result. The experiments were very interesting and in a way wonderful. See Fig. 382 (experiments Nos. 1 to 9). No. 1 shows the magnetic character of liquid oxygen. A test tube with a side tube is filled with liquid

FIG. 382.

oxygen and a cork inserted. The side tube allows free evaporation to take place. This is suspended and an electro magnet brought near the end of the tube, when the tube swings toward and adheres to the pole of the magnet as if it were a piece of iron.

No. 2. Steel burning in liquid oxygen. A carbon is heated in the stove until the end is red hot, then it is put into a glass of liquid air and burns very brilliantly. One peculiar feature is the liquid air does not seem to touch the carbon at all; there is a space between the carbon and liquid air of probably one quarter of an inch.

No. 3. Frozen sheet iron.
No. 4. Explosion of confined liquid air.
No. 5. Burning paper.
No. 6. Explosion of sponge.

No. 7. Freezing rubber ball.

No. 8. Double-walled vacuum bulb.

No. 9. Boiling liquid air. Prof. Tripler put some of it into a tin kettle, set it on a hot stove, the vapor came out through the nose of the kettle as if it were boiling water. He poured in a glass of water, which went to the bottom of the kettle, and after setting on the hot stove until the liquid air was evaporated, the water was found frozen solid over the bottom of the kettle, while setting on the hot stove.

Fig. 383 (experiments Nos. 10 to 14).

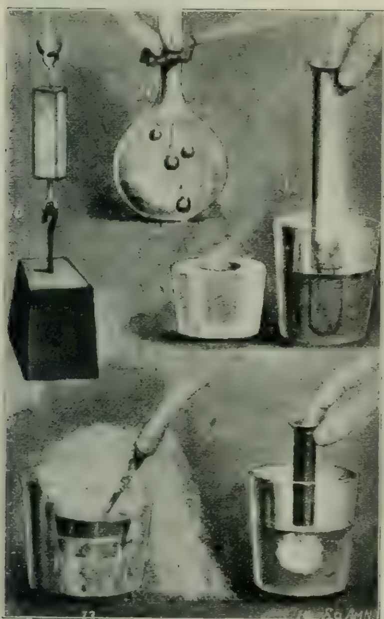


Fig. 383.

No. 10. Frozen mercury.

No. 11. Liquid oxygen in water. Into the top of the flask liquid air is poured. This at first floats, but as the nitrogen boils away leaving the oxygen behind, the drops of oxygen begin to sink into the water. As these drops sink they are partially turned into vapor which rises through the water. This action communicates a rapid whirling motion to the oxygen, and drives it back again.

No. 12. Frozen whisky.

No. 13. Carbonic acid snow.

No. 14. Burning carbon in liquid oxygen.

Fig. 384 (experiments Nos. 15 to 17).

No. 15. Liquid air boiling in a vacuum.

Nos. 16 and 17. Force of liquid oxygen.

Greatly to Mr. Tripler's credit he has invented a way of liquefying air, but his work is not accomplished by any means as yet, because now he must learn how to harness this tremendous power in order to utilize it. One cubic foot of liquid air represents about 800 cubic feet of free air.

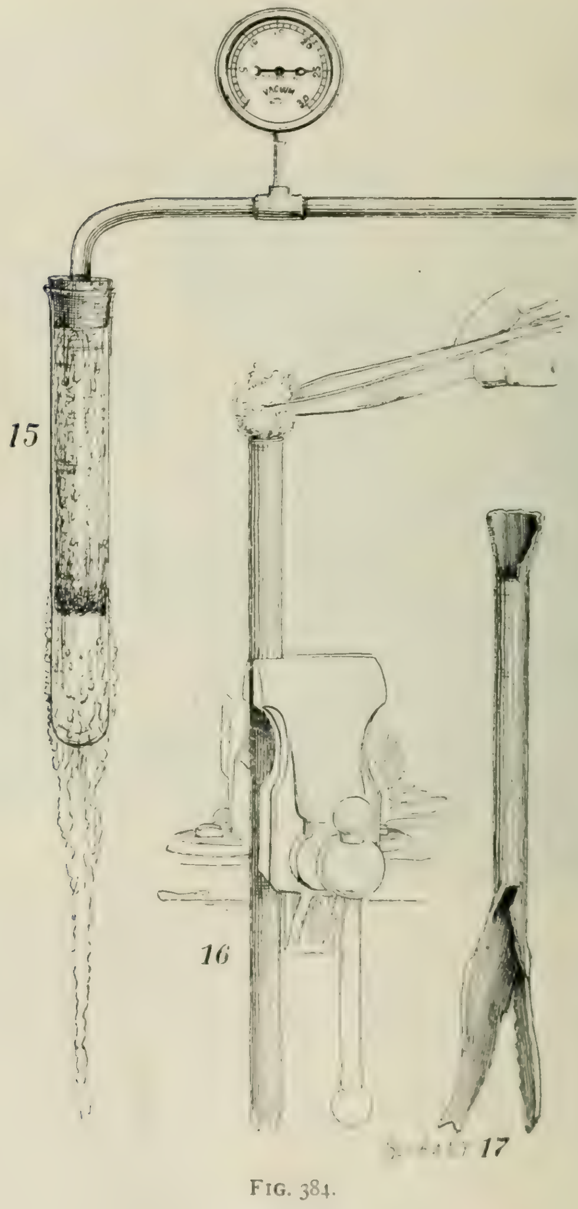


FIG. 384.

FIG. 385. PLANT FOR LIQUEFYING AIR.

[NOTE: Thanks are due Prof. Tripler, also B. C. Batcheller and the Scientific American for information given.]

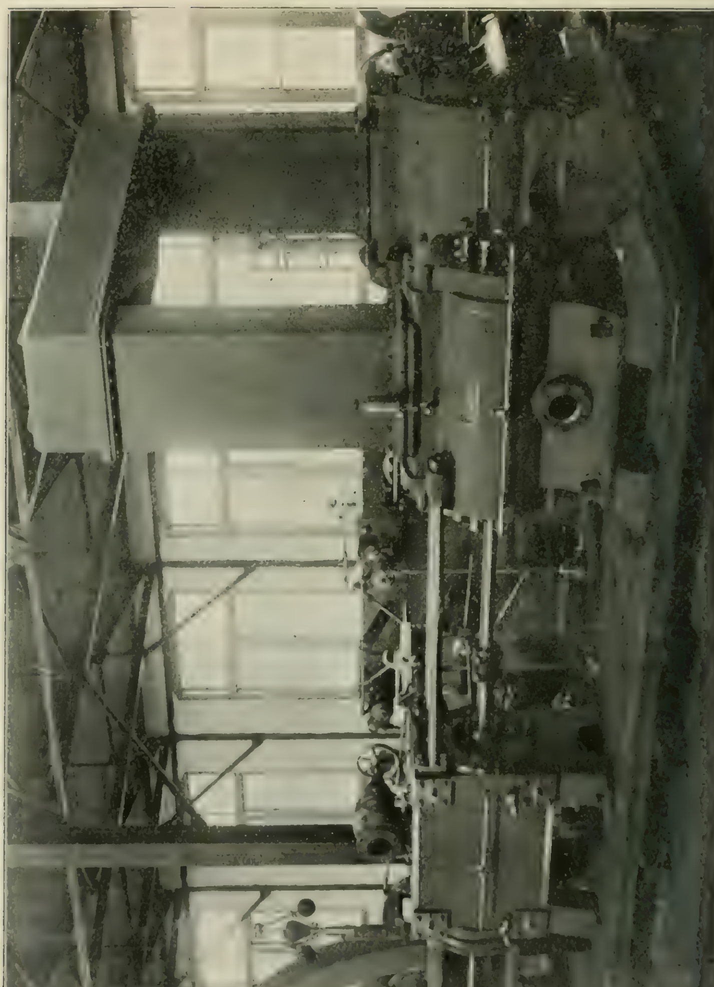


FIG. 386. RAND AIR COMPRESSOR FOR WOLVERINE COPPER MINING CO.
Corliss engine, compound steam cylinders, 18 and 34 x 36; compound air cylinders 30½ and 20 x 36 with intercooler.

COMPRESSED AIR.

By Charles W. Melcher, Mem. W. S. E.

A paper on "Compresssd Air," read before the Franklin Institute six years ago, states that in common practice where compress air is used to drive machinery in mines and tunnels 70 per cent. of the power is lost, and in the best practice with the best compressors and without reheating, a loss of 60 per cent is entailed.

At that time the operations of mining and tunneling and the sinking of bridge caissons, comprised the principal uses of compressed air in this country, and for this work the question of economy was of secondary consideration.

At the same time, in Paris, a compressed air plant of about 2,500 horse-power had been in use for several years, transmitting power over the city to operate clocks, drive engines and other pneumatic appliances. In this plant the air was transmitted to motors four miles from the central power station and reheaters were employed. An average efficiency of 50 per cent under the above conditions is conceded in Professor Kennedy's report on the system.

Since that time compressed air has gradually come into very general use. We are daily finding for it new applications of widely different character, and the question of efficiency, both as to cost of production and its use in properly designed motors, comes prominently before us.

Some important uses of compressed air require very moderate pressures, ten to twenty pounds being ample for the proper operation of the sand blast method of cleaning castings for spray painting, now largely employed on structural work, and for the pneumatic tube system of mail transmission, now employed in New York, Philadelphia and Boston.

For this light pressure the simplest form of compressor is used, the familiar "Straight Line" type being the favorite on account of lower first cost. The small machines have plain slide valves, while for large capacities the Duplex compressor, with Meyer cut-off or Corliss steam end is employed.

The M. E. P. produced in compressing air to 15 pounds gauge is, for isothermal compression, 10.3 pounds, and for adiabatic compression 11.5 pounds; showing that at the low pressures employed above the losses due to the heat of compression will not exceed 10 per cent, even if we allow nothing for the cooling effect of the water jackets. Consequently in the production of compressed air at these low pressures a high efficiency is easily attained.

For general shop requirements, employing air pressure from 60 to 125 pounds, the simple "Straight Line" compressor is largely used; but is being rapidly superseded by the Duplex Compound, or two-stage type. This pattern of air compressor, when pro-

vided with an efficient intercooler between the high and low pressure air cylinders, effects a saving in the power necessary to compress the air of from 10 to 15 per cent on pressures ranging from 60 to 125 pounds. The duty of the intercooler is to reduce the temperature of the air received from the low pressure air cylinder, and deliver it to the high pressure cylinder at a temperature as low or lower than that of the intake air.

The steam end is usually provided with the Meyer cut-off valve gear, and the speed of compressor is regulated automatically by air pressure operating a throttle regulator. Where higher economy is desired a Corliss steam end is employed, the pressure regulator varying the point of cut-off in accordance with the volume of air required.

For still higher pressure, up to 5,000 pounds, three and four-stage compressors are employed, using intercoolers at each successive stage.

The air end of a four-stage air compressor recently designed to furnish air at 2,500 pounds gauge pressure, has dimensions of air cylinders as follows:

Intake cylinder	21¼″
1st intermediate cylinder	9″
2nd "	7″
High pressure	3″
Stroke	36″

With an intake temperature of 78.5 degrees F. the air leaves the fourth or high pressure cylinder at a pressure of 2,500 pounds and a temperature of 214 degrees F. A compressor of this type is now under construction for the Cambria Iron Company and will be used to compress air to 850 or 1,000 pounds for compressed air haulage. Another four stage compressor of 1,000 horse-power is now under construction for the Metropolitan Street Railway Company of New York City, and will furnish air at 3,000 pounds pressure for operating twenty compressed air street cars on the Twenty-eighth and Twenty-ninth street lines.

Compressed air locomotives, now employed for underground haulage in many collieries, store the air at about 600 pounds pressure in two steel tanks, having a capacity in proportion to the length of run. These tanks have an unusually large factor of safety, and are tested up to 1,000 pounds hydraulic pressure for a working pressure of 600 pounds. From the tanks the air passes through a reducing valve into an auxiliary reservoir where the air is maintained at the pressure required for operating the motor. A pipe line conducts the air to charging stations located at convenient places, and a locomotive is charged in one and one-half minutes.

The following outline of a compressed air haulage plant in actual operation may be of interest:

Air compressor, 3 stage: Steam, 20″x 24″
Air, 12½″, 9½″ and 5″x24″.

Capacity: 275 cubic feet free air to 600 pounds pressure.

Main air pipe 5″ diameter, 4,380 feet long, and contains 580 cubic feet of air at 600 pounds pressure; equivalent to 23,000 cubic feet of free air. The main air main has four charging stations, and the branch pipe, 3″ diameter and 3,100 feet long, supplies air at three points.

Two compressed air locomotives are used. Cylinders 7″x14″, drivers 24″; weight, 8½ tons; tank capacity, 130 cubic feet at 600 pounds.

The runs are from 2,100 to 4,000 feet on grades up to 2¾ per cent. A train averages about 15 cars, weighing loaded about 9,800 pounds each.

The two locomotives together haul about 650 cars per ten hours, replacing 27 mules.

Total ton mileage per day of both locomotives..................................	2,167
Cost of operation, including interest, repairs and depreciation, per day........$	17 21
Operating expenses per ton mile, gross...	8-10c
Operating expenses per ton mile, net.....	1 43-100c
Operating expenses by mules ton mile, net..	3 66-100c
Showing a saving per year in favor of air haulage of..........................	$6,590 00

One of the above locomotives has hauled a train of 16 empty cars, or 60,000 pounds, 3,700 feet, returning same distance with 16 loaded cars, or 166,000 pounds, one charge of air serving to make the round trip, starting with a pressure of 575 pounds and ending with a little over 100 pounds.

The working pressure usual in an air locomotive is 150 pounds, which may be maintained constant or varied at will to meet the conditions of work or grade. Depending upon the length of run, and the time lost in making up trains, from 25 to 50 miles per day of 10 hours are made by each locomotive.

Compressed Air is the most important factor in the operation of the Holland Submarine Torpedo Boat, which is just now attracting considerable attention. The dimensions of the boat are :

Length 53 feet; diameter 10′—3′′; Displacement 75 tons; Air Ingersoll-Sergeant Belt Driven Air Compressor, of special construction, supplies the required volume of air at 2,500 pounds pressure. The air cylinders are two in number and single acting. Low pressure cylinder is 6′′ diameter and the high pressure 1¾′′ diameter, with a stroke of 8′′. For cooling the air during compression, both cylinders are immersed in a water box. When the boat is on the surface the compressor is operated by a gasoline engine; but when submerged a storage battery and electric motor furnish the motive power.

The capacity of the Air Storage Tanks is sufficient for a submergence of the Torpedo Boat for ten hours.

All the air required for the respiration of the ten men comprisprising the crew is furnished from these tanks. The steering gear is also operated by compressed air, and the same power furnishes the means for submerging the boat and bringing it again to the surface when desired. This is accomplished by means of a series of steel tanks which are filled with sea water when it is desired to submerge the boat. This same water being expelled by air pressure allows the boat to quickly rise to the surface.

The high efficiency now secured by properly designed Air Compressors seems destined to a sudden increase, if the suggestions advanced by Mr. Frank Richards in a recent issue of the *American Machinist* are realized.

This is in line with the experimental work of the Cumming's Double Type Air Compressor on the Pacific Coast, and illustrates some of the possibilities which may be in store for Compressed Air.

Instead of compressing to 100 pounds gauge pressure and exhausting from the motor at atmospheric pressure, Mr. Richards proposes to raise the initial pressure, or the pressure before compression, to, say 100 pounds, and carry on the same cycle of operations at a higher range, compressing to 200 pounds and exhausting from the motor against 100 pounds back pressure, this air to be returned to the compressor and recompressed for use as before.

The range of air pressures being the same in either case, namely, 100 pounds, the M. E. P. on the motor piston would obviously develop the same amount of useful work when used without expansion, as is the case with nine-tenths of the air motors employed in general shop work.

The saving in cost of compression is in the smaller heat loss experienced at the higher range. If we compress 100 cubic feet of free air to 100 pounds gauge pressure, the resultant volume of compressed air available for use after the air has dropped to normal temperature is 13.04 cubic feet, but if we raise our initial to 100 pounds gauge and compress to 200 pounds, we secure a final volume of 53.5 cubic feet, or more than one-half our initial volume.

Now, the M. E. P. on the compressor piston is 41.6 pounds for the 100 pounds air and 78.88 pounds for the 200 pounds air, and if we divide the M. E. P. in each case by its corresponding volume, we will have a comparative power cost of the same volume of air at the two pressures, or 319 for the low pressure air against 147 for the high pressure air. The above figures are based on simple compression. If we take advantage of two-stage compression in supplying the air at 100 pounds the ratio becomes 274 to 147, or still nearly two to one in favor of the high pressure.

The available volume after compression is also four to one in favor of the higher pressure, enabling us to use an air compressor of one-fourth the capacity required under ordinary practice, and but one-half the power will be required to operate it.

The principal difficulty in making the above plan available in ordinary shop practice is the greatly increased liability to leakage with the high tension air, but this is not necessarily insurmountable.

The President: The case of transmission of air has been very ably presented by Mr. Lewis and Mr. Melcher, and the chair will ask Mr. Westover to introduce the discussion in regard to

MECHANICAL POWER TRANSMISSION.

Mr. H. J. Westover read as follows:

We have been listening to the many methods employed in transmitting power from a central source to the machine to be driven. Some of these methods appear to be best suited to special purposes, whilst others, for instance, electricity, lend themselves to a more general application.

Mechanical transmission by shafting and belts is one of the oldest methods and at the same time the one most extensively in use at the present time. This is an age of progress—the best all-round method will be at the front

With the rapid progress made in recent years in bringing to perfection other methods and considering the high efficiencies claimed for them it looks very much as if this method of transmission would soon be relegated to the past.

It is a matter of considerable importance, however, to know exactly what are the relative efficiencies of the many methods, before discarding one that has held its own so long a time and in which there has been so much money invested.

It was with this in view that the following tests were made in several factories forming one of our large industrial concerns in this city.

These tests were carefully made by myself to determine the losses at and from the engine to the machines to be driven. Before giving you the figures, however, a few remarks concerning the conditions of the factories and the shafting, also the method employed in obtaining these results, will not be out of place.

The use of machinery has been rapidly extended during the past ten years in all of our large industrial establishments. This machinery has not been placed all at one time and properly arranged for, but has been added from time to time, when such machinery has been found suitable for the work to be done. In the placing of this machinery it has not been a question of how near it can be located to the central source of power; the most convenient place for the handling of the material has been the place where the machinery had to be located, consequently you

will find the machinery scattered over large areas of floor space. These machines will be of varying sizes, requiring from 1 to 35 horse power to operate at full load.

The factories in which the following tests were made had the machinery arranged on five floors in each building with freight elevators running from the basement to the fifth floor.

The character of the buildings were what is known as "mill construction." On each floor there was one or more line shafts. The engine was on the first floor, and in each case was belted to a countershaft on the second floor. The line of shafting on each floor was driven from the line of shafting of the floor below. In handling the material in the process of manufacturing, due to the shifting of great weights from one part of the floor to another, it was impossible to keep the line shafting true for any length of time, due to the deflection of the floors.

These are the conditions that have to be met, and they are far from being the ideal conditions for transmission of power by belting. This shafting and belting, however, was well taken care of, and would compare very favorably with any other factory or mill.

The method of making the tests was as follows:

Each engine was indicated at a time when the factory was not in operation, considerable care being taken to see when the engine was started that all the shafting on every floor was turning, and that all the belts running, including belts on the loose pulleys of the machines. When the engine was running at its normal speed, cards were taken and an average friction card thus obtained. The same method followed later in the day when the factory was running at its usual output, the average of the cards taken giving the average load.

The factories are designated by a number, and the results of the tests as each factory are as follows:

	Friction load	Full load	Useful load	Per Cent. of useful load to full load
No. 1	34 I. H. P.	96 I. H. P.	62 I. H. P.	64½
" 2	126 "	217 "	91 "	42
" 3	38 "	60 "	22 "	36⅔
" 4	88 "	123 "	35 "	28½
" 5	95 "	130 "	35 "	27

It will be noticed that we have a variation from 64½ per cent to 27 per cent; taking for example No. 1 factory with 100 I. H. P. at the engine there was transmitted as useful work to the machines 64½ I. H. P. at a loss of 35½ I. H. P. in transmission. At No. 5 factory 100 I. H. P., at the engine gave only 27 I. H. P. as useful work with a loss of 73 I. H. P. in the transmission. This is taking a uniform basis of 100 I. H. P. at the engine for comparison. In No. 1 factory all the heavy machinery was belted from the first countershaft, leav-

ing a few small machines scattered around. In No. 5 factory the greater part of the machinery was on the fourth and fifth floors, requiring six belt transmissions to reach the machinery from the engine with a few small machines scattered on the first, second and third floors.

In No. 4 factory the arrangement of the machinery was similar to No. 5.

From these tests it appears that when machinery can be arranged so that the transmission is through one line of shafting from the engine to the machine, the efficiency obtained will compare favorably with any other method of power transmission.

When the machinery cannot be so conveniently arranged, and when it will be necessary to transmit the power from the engine o the machines through three or more lines of shafting, the efficiency of a belt transmission falls so low that some other method will be more economical.

Mr. Clark: I would ask Mr. Westover if he made any comparison on the efficiency of the system after he put in electric motors and before he put in electric motors on the shafting? He said they were replaced by electric motors and he checked up the readings on the engines for its useful load. Can he give us any comparison of the efficiency obtained by that test?

Mr. Westover: I cannot give any comparisons; I made no test after the electrical installation was made. That has only recently been made and the tests of those I suppose will be made within some two weeks, when we can get a comparison between the two.

Mr. Robt. R. Arbell next presented views of rope transmission in use in various shops in Chicago, describing each in its turn. This subject was fully described and illustrated in No. 3, Vol. II., 1897, of the Journal of this society.

The President: The subject is open for general discussion. Is there any member that has anything to offer on the subject?

Mr. T. T. Johnston: It seems to me that this subject is much too bewildering for me to talk intelligently upon. We find in one place compressed air driving a generator and in another place a generator driving an air compressor; in one place we have a rope drive driving a pump and in another place we have a pump driving a rope drive, and so on, and it makes the subject too complicated.

I have very little to say on the subject excepting perhaps in regard to one thing that has been touched upon, and that is with regard to transmission of power by water. It is very frequently done, and the particular thought that was floating in my mind is the great advances that have been made in the design and manufacture of water motors, especially pressure wheels under very high heads. There has been constructed very recently by an

American concern a turbine wheel to operate under a head of 260 feet; I have seen a design of one to operate under 260 feet to generate 3,800 horse power, and the whole machine could be put in one end of this room very comfortably, the result of which has been to enable large units to be generated under quite high heads, something that has hitherto been out of the question. I think perhaps if the Niagara people had their work to do over again to-day, they would do it differently from what they have done, on account of the great strides that have been made in making water motors, and other appliances.

A Member: I would like to ask if any one here is able to state whether there has been any application of electricity to the modern flouring mill and with what success?

Prof. Jackson: There are many flouring mills driven by electric motors. The motors in some cases are driven from central stations in which steam engines are the prime movers, and in other cases they are driven from central stations in which water wheels are the prime movers.

A Member: May I expand that question to the extent of asking, are there any of the large mills, that is, those who are operating and turning out thousands of barrels a day, that are driving their machinery by electricity?

Prof. Jackson: There are a number of large mills, but I cannot give their capacities. Success in electric driving in this case is not a question of capacity of the mill; it is a question of the steadiness of the power. Satisfactory results have been obtained in various mills that have been equipped in regard to steadiness of power; and the extension to larger mills is purely a question of using more or larger motors.

A Member: Do you know if the power is applied directly to the roller itself or to the general shafting of the mill?

Prof. Jackson: That depends upon the arrangement of the mill itself. It is seldom that a motor would be applied to a single set of rollers; the mill may be divided into several sections, to each of which a motor is connected, or a single large motor driving the entire mill may be used. External circumstances often control this question.

Mr. Coster: We have recently submitted a proposition on a 900-horse power motor engine, 150 revolutions per minute, for driving a flouring mill, the motor, probably, to be installed within the next six months.

A Member: That would apply to the general line of shafting, the same as this?

Mr. Coster: Yes, that would apply, but this mill is driven by water power, but sometimes the water power gets low and then they use a motor driven by electricity.

Mr. Johnston: At Portland, Oregon, there is a flour mill of 1800 barrels a day capacity operated by an electric motor—the capacity of that is 1400 kilowatt. That I saw last winter, and is giving very satisfactory service.

XXXV

GAUGING OF STREAMS.

By William G. Price, Mem. W. S. E.

Read May 18, 1898.

The writer will not undertake to describe all the methods of veocity measurements now used, but will give a description of some of the methods which have been used by him during the past nineteen years.

So much has been written upon this subject that very little is left to be said, except to describe more in detail the work of discharge observation.

The experience of the writer began in the year 1879, on the lower Mississippi River, where attempts were made to use the Ellis and Herschel current meters. It was soon seen that these meters were not adapted for use in sediment bearing streams where sand cut the bearings of the Ellis, and floating leaves and grass clogged the wheel of the Herschel. The discharge was measured that year with double floats, and required four observers on shore, one at each of the three range lines, 100 feet apart, and one to take angles, besides two skiff parties, one to put out the floats and one to take them in again. At first the observers at the range lines were to call time as the float passed the range, loud enough so one of them could time the float with a stop watch and the man at the instrument at the end of the base line could take the angle to locate the position of the float in the river. When the work began one of the observers at one of the ranges, who stuttered, was unable to say time just when the float was on the line, although he made heroic efforts to do so. A telegraph system was then installed and each observer had only to press a key at the proper instant. The method with double floats was not very satisfactory. Owing to the eddies and boils, the lower float was sometimes ahead of, and sometimes behind the surface float, and as the upward current in the boils was very strong, it is probable that the lower float was at times near the surface. There were four observers on shore, and the accuracy of the work depended on each of these observers, as well as on the man who adjusted the length of string between the surface and the sub-surface floats. One careless man could render the whole work inaccurate, and the chief of the party had no check on anyone. Notwithstanding these defects in the method, the work done was remarkably good for the time and place.

The next year several parties began work on the upper Mississippi River. The first work was to measure the discharge during

the winter, through the ice, using the Ellis current meter, which in the hands of an expert could be made to do good work in clear water. The meter was first rated in a lake of still water, through the ice. To do this successfully an opening should be cut in the ice, one foot wide, and about 250 feet long. The meter should be attached to its rod and weight, and suspended two or three feet below the ice, from a sled which straddles the opening, and which carries the observer with his battery, register and stop watch. The ice must be made level where the sled runners are to pass, so the meter will be carried without any up and down movement. A base line of 200 feet should be measured along the opening, and each end should be marked by a range made by two flags at right angles with it. The sled should be drawn back and forth at low, medium and high velocities, the stop watch and register being started on the first range line, and stopped on the second. Several ratings like this were made by the writer during the winter of 1880-81. When using the meter in winter it is necessary to protect the suspending rope and insulated wire from freezing, otherwise they will become so coated with ice that they cannot be manipulated. The method used by the writer on the Mississippi and Missouri rivers was to build a small house on a sled. The house was just large enough for one man to sit inside, leaving room at one end for a very small stove and room at the other end to lower the meter into the water through a trap door. The sled had board runners, curved to run forward and back, and had a rope at each end to draw it by. The house consisted of a light wood frame, which was covered on sides and top with heavy canvas, and had a canvas door, all of which was given one coat of linseed oil. A reel near the roof, at one end, carried the steel meter suspending rope and insulated wire. The shaft of the wheel passed through the side of the house, and there was a crank ratchet and pawl on the outside. The suspending rope and insulated wire were each connected with copper rings on the reel, and springs made contact with these rings and completed the electric circuit to the meter, register and battery. Two men were required to measure a discharge, one to sit inside and record the soundings, registrations and time, and the other to cut holes in the ice, draw the sled, feed the fire and turn the outside crank when the meter was to be raised and lowered. Holes were cut in the ice in a line across the river, and measurements were taken through each at mid-depth, for the discharge. Many vertical velocity measurements were also taken, so as to determine the correction required to reduce the observed mid-depth velocity to the mean velocity.

This work was continued on the Mississippi until on the 6th of April the ice started with our party in the middle of the river, and we had to get to shore by jumping from one cake of ice to another. One problem which at first seemed difficult was to measure the height of the water which was required each day be-

fore and after the measurement of the discharge. If a post was driven into the ground through a hole in the ice, and the gauge board was nailed to it, the ice would freeze to it in a few hours and a rise or fall of the river would lift or pull down the post, and then the ice had to be cut off of the gauge board twice a day so it could be read, and the graduations were likely to be cut off at the same time.

One chief of party, who was making heroic efforts to secure correct gauge readings when the temperature was 30 degrees below zero, finally wrapped up the gauge post with a fine wool blanket with the lower edge of the blanket in the water. This surely was expected to keep the gauge warm, but much to his disappointment, the next morning the blanket was solid ice, and had to be chopped away also. The best plan is to cut a hole in the ice where the water is about four feet deep, and then drive a stake through the hole into the ground, using a follower till the top of the stake is below the bottom of the ice. Level from the top of the stake to a bench mark, and read the gauge with a small graduated rod, the end of which has a board about four inches square nailed to it so it will be easy to find the top of the stake and rest the rod upon it. Of course the hole in the ice has to be chopped open every day, and the graduated rod has to be taken into the house and the ice melted off of it after each reading of the gauge. After the ice was gone the discharge was measured with rod floats. A wire anchorage was first placed across the river. The cross wire was of No. 10 steel, and it was supported from being carried down the stream by the current at points 80 feet apart by anchor wires, which led up stream to large stone anchors. The anchors weighed 250 pounds, and the length of each anchor wire was five times the depth of the water. The cross wire was made in links 80 feet 4 inches long, which were joined by a two inch ring of ¼ inch round iron. The anchor wires were attached one to each ring. This made the stations for discharge measurements 80 feet apart, as the 4 inches was required for down stream sag in the wire between stations.

When not in use the wire lay on the bed of the river, and the movement of sand reefs down stream would occasionally bury it so deep it required a hard pull to lift it up again. It had to be raised every day during high water to keep it from becoming buried too deep in the sand, and to remove the large mass of leaves and grass which moved along the bottom of the river and collected upon it. In lifting the anchorage it was under-run by a skiff which passed from shore to shore in opposite directions each day; as the slack in the wire followed the skiff it could not be under-run twice in one direction without breaking it.

In places where the cross wire was suspended a few inches above the bottom of the river, the sand in suspension in the swift current would collide with it, and would cut the metal away so fast it had to be renewed several times during the year.

This possibly explains why many of the bank revetment mattresses on the lower Mississippi River, which were bound together with wires, have disintegrated rapidly.

There was a sheave in the bow of the skiff over which the wire was carried, and a crank attached to the sheave enabled the skiff to be propelled back and forth across the river quite rapidly. There were many steamboats passing up and down the river, nearly one hundred of them being employed in towing rafts of logs and lumber. It seems that the pilots thought at first that we had a new scheme for catching fish, and they did not mind running down an ordinary fisherman, as one of them explained to me afterward, so as each steamboat came along, they steered straight for us just to see us spin along on the wire to get out of the way. But one day the wire got caught so we could not move, and they ran over us. No one was drowned, but after that we put up "Old Glory" and refused to run, and all steamboats steered clear of us. Across the stern of the skiff was placed a board one inch thick, six inches wide and twenty feet long, and from the ends of this board wires one hundred feet long extended down stream to a similar board, which was carried on iron floats so as to be a few inches above the surface of the water. The up-stream edge of the board on the floats was covered with sheet copper, and a wire was stretched in front of it so that a float striking the wire pressed it against the copper. Suitable insulated wire connections were made with a battery, and telegraph sounder in the skiff. Each float was loaded with shot at one end till only about six inches of it projected above water. They were put into the water from the bow of the skiff, and as they passed the edge of the board, the watch was started, and when the float struck the wire, which made the run one hundred feet, the wire was pressed by it against the copper strip, and the telegraph sounder gave the signal to stop the watch, which gave the correct time of a one hundred foot run of the float. The floats were picked up by a man in another skiff, and brought back for use again. Several floats were run at each station, and the mean of all the times was taken when computing the discharge. When the current was swift a discharge measurement could be made quite rapidly with this apparatus. Two sections were sounded one hundred feet apart and the mean of the two was used in computing the discharge.

The next year, 1882, the writer was stationed on the Ohio River at Paducah, Ky. A wire anchorage was built here also, but it was soon destroyed. A mass of leaves and grass collected on the wire, and they offered so much resistance to the current the wire was soon broken in many places. The discharge was then measured with the current meter, which was suspended from the stern of a catamaran. The catamaran was lashed alongside of a steam launch, and the two were anchored so as to locate the meter on the discharge section. There was a "V" in the anchor rope, to

prevent swinging of the boat, one branch running to the catamaran and the other to the launch. The meter and weight were supported by a No. 10 steel wire, which was graduated to feet by a winding of fine thread wire soldered to it. The insulated wire was wound around the meter-suspending wire, which was found to be necessary, as, if it was only tied to it, it would vibrate in the current and soon break where it was tied. The lead weight weighed about 100 pounds, and was held from being carried down stream by the current by a guy line of ¼-inch cotton cord, which was fastened to the up-stream end of the lead weight about one foot below the meter, and led up stream to a sheave in the stock of the big iron anchor which held the boats in position on the discharge section. From the sheave the guy line extended to the bow of the catamaran, where it was fastened to a kevel. The guy line was paid out and hauled in at the same time as the main anchor rope, and gave no trouble in any way. As the guy line led from the meter weight up stream and down to the bottom of the river, it gave a downward pull on the wire which supported the meter and weight, thus keeping it vertical, and preventing all down-stream sag. The meter could be located precisely at any depth desired. This plan worked especially well when measuring the vertical curves of velocity. The catamaran was anchored at as many points on the section line each day as was necessary to secure an accurate discharge measurement. The position of the catamaran at each anchorage was determined by a sextant on the catamaran, and a base line on shore, which was at right angles to the discharge section. The sextant was made by a tinsmith in two hours' time. It had no graduated arc, but was set permanently to give an angle of $14^\circ\ 02'$, which is an angle in a right-angled triangle, such that the perpendicular is four times as long as the base. The base line on shore was graduated by white cloth signals, so that the distance from the base to the meter could be read by the number of signals covered by the mirrors in the sextant. The probable error in measurement was not over two feet. At first an attempt was made to use the Ellis meter, but the sand in the water cut the bearings, and the drift logs broke the wheel and finally carried it away. The Herschel meter was then used, but leaves and grass immediately clogged the wheel. As the great flood of 1882 was on the way down the Ohio, and must be measured, the writer employed a blacksmith and a locksmith, who were the best mechanics in the town, and in less than two days they built a meter which was strong enough to do the work. This meter gave excellent results, and it was used for over two years on the Ohio and Mississippi rivers without being worn or battered in any way, and I believe it is still in good condition.

The next year the writer was at Carrollton, Louisiana, on the Mississippi. Anchors could not be used there, owing to the great depth and the high velocity of the current. Range lines were marked on shore by white cloth signals in such positions that the

ranges crossed the discharge section line at all the points where velocity measurements were desired. These range signals were placed a long ways up stream from the discharge section, so that the angles of intersection would be as large as possible. When measuring the velocity the pilot steered the boat so as to keep his head on one of the range lines, and the engineer, with his hand on the throttle valve, kept his head on a line of signals which was parallel to and the same distance down stream from the discharge section as his head was down stream from the head of the pilot. The boat was thus held so it could move but very little from the proper position, and as the stop watch and register were started and stopped when the engineer was just on line, all error from the movement of the boat was practically eliminated. The meter and weight were suspended from the stern of the catamaran by a single steel wire. A better plan, in the opinion of the writer, would be to suspend the meter from an outrigger projecting up stream from the bow of a steam launch or tug so as to keep the meter away from the disturbing effect of the hull and propeller. The meter weight was suspended on a trunion, placed at its center of gravity, and it had a vane the same as the meter, which always kept it in line with the current, both in the vertical and horizontal plane. The meter was fastened to the rod one foot above the weight, so as to be clear of the current disturbing influence of the weight. The weight was very heavy and no guy line was used. The swift current swung the meter and weight down stream a little, but the suspending wire remained nearly straight from sheave to meter, which would not have been the case if a guy rope had been used, leading from the meter up to the bow of the boat which has since been the usual practice on the lower Mississippi River. The velocity for discharge was measured at mid-depth, and to locate the meter at mid-depth, it was first lowered till the weight touched bottom and the depth was read on the graduated suspending wire. One-half of the total depth was taken for mid-depth, and the meter was raised to that point. Owing to the current having swung the meter weight a little down stream, the depth as measured in this way was a little more than the true depth, and was not used in computing the discharge, but by this method the meter was located at mid-depth with much greater accuracy than would have been possible if a guy line leading directly up stream to the bow of the boat had been used. A guy line would have pulled up on the weight so much the suspending wire would have been very much curved instead of being practically a straight line. When measuring the vertical velocity curve by this method the total depth was measured as before, and then the meter was run at all the tenths, twentieths or thirtieths of that depth, and again much more accurate work was done than could have been done if the guy rope had been used.

Another method for measuring the discharge with the meter

called the "Flanking Method" has since been used, and it evidently serves at least as a good check on the stationary method. In the Trans. Am. Soc. C. E., Vol. 35, page 333, Mr. Arthur Hider describes it as follows: "First, to submerge the meter fifteen feet, or if necessary twenty feet below the surface, so as to be below any disturbance caused by the movement of the boat; second, to start the boat at a slow rate of speed across the river, keeping on the discharge range, noting the registration of the meter and the time of passage between each division; third, to sound the section during, or immediately after the meter observations are taken."

In measuring the discharge of the Missouri River at low water, and at many places between Great Falls and Sioux City, the writer used the following method: Usually only two or three measurements were made at one place, so no permanent discharge station was established. The discharge section was selected and marked with one flagpole on one side of the river, and two flagpoles on the other side, one pole being far back from the water's edge, so as to give a well defined range. A base line was then measured at right angles to the discharge range, and extending up stream or down stream, and was marked at each end with flagpoles. The length of the base line was made equal to the estimated width of the river in even hundreds of feet, to facilitate computation of the discharge. This made the smallest angle of intersection in locating meter stations about 45 degrees, which is not too small for accurate work. The distance from the base line to the water's edge was then measured. The velocity was measured and the soundings were taken at the same time from a skiff which was anchored successively at all the points on the section line where velocity measurements were desired. The skiff was held by two anchors placed some distance apart, with the anchor ropes leading to the bow of the skiff so as to form a "V," which held the skiff quite steady except when there was a cross stream or up stream wind, when a third anchor had to be thrown out from the stern of the skiff. The anchors used were old cast iron wagon skeins, which were efficient, and at many places there was no stone or other iron to be found. The location of the skiff at each point where it was anchored was made by measuring an angle to the base line signals with a sextant, care being taken to have the sextant on the section line, and at the same elevation above the water surface as the flagpole signals were. Shallow soundings were measured with a pole, and deeper ones with a lead and line.

The points for velocity measurement were made near together where great changes in depth and velocity were noted, and farther apart at other places. The meter was suspended from an outrigger which had a sheave in the end, and which projected three feet up stream from the bow of the skiff. A reel in the skiff attached to the outrigger was used to wind up the meter suspend-

ing wire, and insulated wire, which was wound around the suspending wire. By means of copper rings on the reel, connected to the insulated and suspending wire, and springs on the outrigger in contact with them, the electric circuit was completed to the battery and register. The anchor ropes passed over the outer end of the outrigger, as this was necessary in order to hold the skiff steady. The meter suspending rope was of ¼ inch steel, and it was tagged, and the weight was the same kind as that which was used at Carrollton, La., except that it was not so heavy. The meter was first lowered till the weight touched bottom, and the depth read on the rope; then it was raised till the meter was down one-half this depth. In swift currents this measurement of depth was not correct, owing to the down stream swing of the weight, and it was not used in computing the discharge, but it enables us to locate the meter correctly at mid-depth in all currents. The time of one hundred revolutions of the meter wheel was usually taken to facilitate computations. The register was started before the stop-watch, and the watch was started the instant the register pointer jumped to a new position, and the watch was stopped when the register pointer jumped to a new position, one hundred registrations from the first one. In this way all error in time at the beginning and ending of the run was avoided.

The measurement of the high water discharge of the upper Missouri River is quite difficult, owing to the very swift current. The writer measured it at Sioux City by suspending the meter from the stern of a large skiff, the skiff being supported against the current by a rope which was over 500 feet long, and was fastened to the railroad bridge. The rope was made long so as to place the skiff as far as possible from the current disturbing effect of the bridge piers. Men on the bridge moved the rope as soon as the measurement at one point was completed. One man in the stern of the skiff attended to the meter, and another in the bow took soundings, and steered the skiff with an oar so as to keep it from swinging from side to side. When moving to a new point the man in the bow of the skiff would catch a range, as, for instance, a chimney and a tree in line, and would hold the skiff on that range till the observation was finished. The velocity was as great as twelve feet per second, and with much drift running. A sharp hatchet was kept in the bow of the skiff, and it was used several times to cut the rope, so as to save the skiff from colliding with cakes of ice and drift logs.

The measurement of small streams can be done with the least labor and time with the Acoustic Meter, which was designed by the writer for this purpose. The electric battery, register, wires and meter weight are dispensed with. The bearings of the wheel shaft are in the air chambers which exclude the water. A worm is cut on the upper end of the shaft and this worm turns a toothed wheel. A pin on this wheel depresses a pin head hammer which is released at every tenth revolution of the meter wheel, and

strikes a diaphragm in the bottom of the tube which is used to support the meter in the water. The sound comes up through

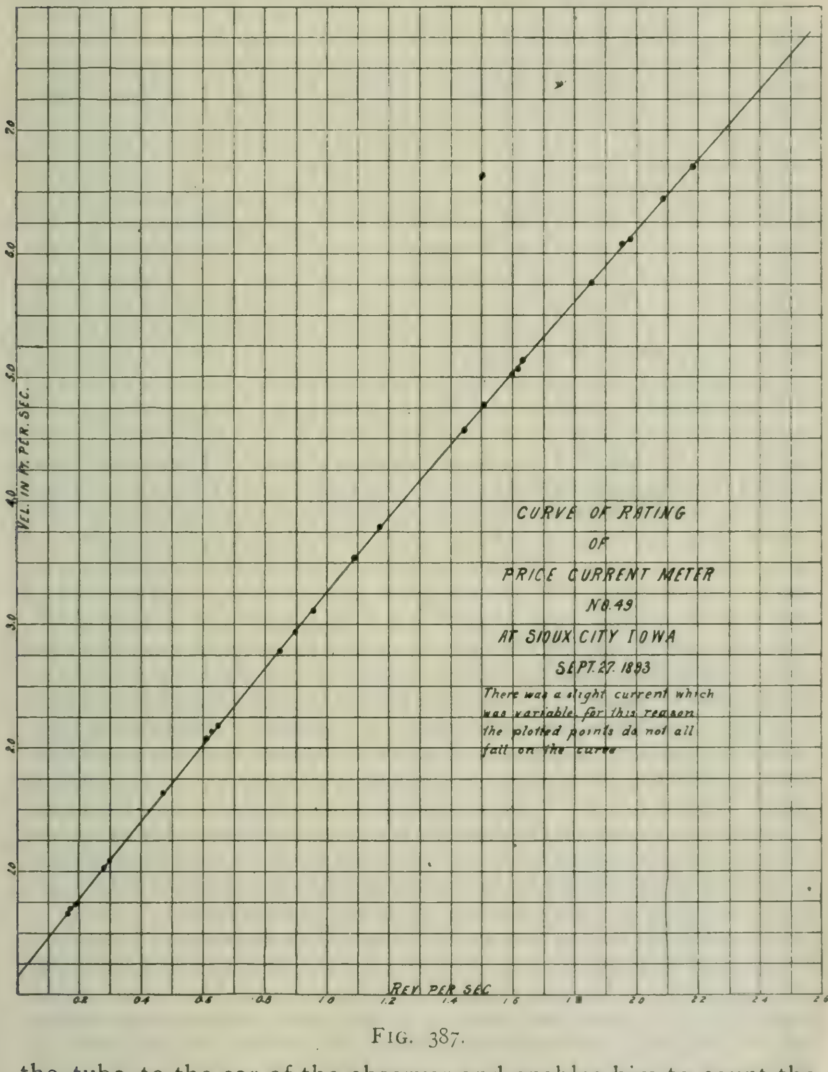


FIG. 387.

the tube to the ear of the observer and enables him to count the revolutions. The tube is graduated to feet and tenths so that the meter can be placed at any depth desired. The meter can be held by one hand, and the stop watch by the other.

When using either the Electric or the Acoustic Meter, the observer should know whether it is in good order or not, or whether

it has been injured in any way, so as not to be in the same condition as when it was rated. Immediately after rating the meter, set the wheel whirling by one quick movement of the hand, in a room where there is no wind, and measure with the stop watch how long a time it requires to come to rest. Repeat this test every day and if any material change is noticed, it should be put in good order, and rated again. Notice frequently if the wheel cups have not been bent out of their original shape by collision with drift wood. Both of the meter bearings and the air chamber, which contains the electric contact breaker, or the pin head hammer, should be oiled every day they are used, and an oil should be used which has a very low cold test, so it will not thicken in cold water. Meters which are so made as to exclude the water and the grit it contains from the bearings, do not change their rate unless they have been injured in some way. The adding of oil to the bearings does not affect the rating. The first meter constructed by the writer was rated several times during the two years it was used, and these ratings varied only a fraction of one per cent, and this variation was probably due to errors of observation. If the meter is a good instrument, and is in the hands of a careful observer, it can not fail to give accurate results. The writer's experience indicates that the only meter which will do good work in water which contains grit, leaves and grass, is one which has a vertical shaft, so that the wheel revolves in an horizontal plane. The bearings of the vertical shaft can be made cup shaped and inverted, so as to exclude the water and grit. And as the wheel rests on a pintle, which is very small, they give a much lower coefficient of friction in the rating than meters with horizontal bearings, so that much slower currents can be accurately measured. By excluding the water and grit, which it is sure to contain, the coefficient of friction of the bearings becomes a constant quantity which is not the case with meters which have horizontal bearings. A wheel revolving in an horizontal plane carries off the leaves and grass which strike it. In recent attempts to measure the flow of water to the power house of the Niagara Falls Power Company, a meter with a wheel revolving in a vertical plane failed to do accurate work on account of the eel grass catching on the wheel so as to change its rate.

Measurements for discharge should be made at a point not lower than mid-depth, for the reason that the vertical velocity curve probably changes less from pulsations of the current at that depth than it does lower down, and the curve is also nearer vertical, so that an error in locating the meter at that depth does not produce so large an error in the measurement of velocity as it would at six-tenths the depth, where the curve departs much more from the vertical.

A discharge section should not be located where there is an eddy. The writer saw one engineer measure the discharge of a very large river each day for two weeks where there was an eddy

running up stream fully one-fourth as large as the down stream flow, and his notes contained no mention of an eddy, and the discharge was computed as though all the water ran one way.

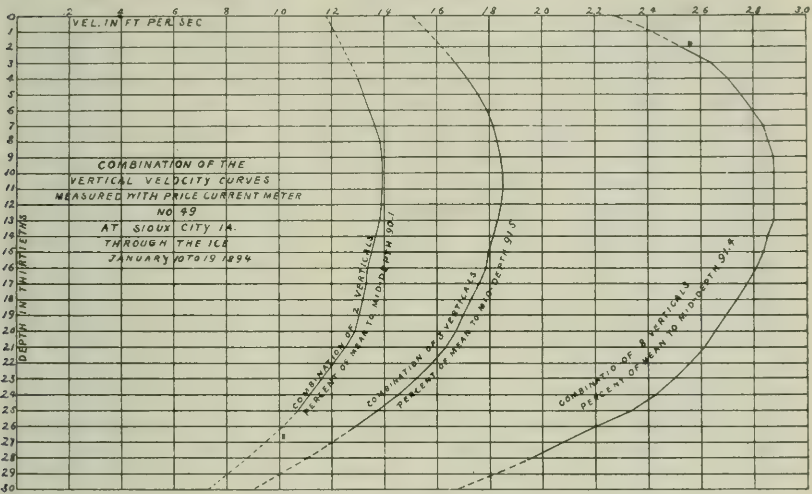


FIG. 388.

The meter can be rated accurately in still water or in water which is moving, provided the velocity of the current is slow and constant. A small, deep pond is the best place. Large lakes, and especially the crescent shaped lakes along the Mississippi and Missouri rivers are not so good for rating meters, as there is liable to be a slow movement of the water back and forth a few feet each way, which will make the rating inaccurate. The writer had this experience and could not account for the results till he put a rod float in the water and watched it for a half hour. The meter should be rated under the same conditions in which it is to be used in measuring velocities of running water. If it is to be used with a steam launch, then, if possible, it should be rated with the steam launch, and suspended from the bow of the launch, and deep enough in the water to be away from the disturbing influence of the hull and the propeller. Sometimes when the meter is suspended from a steam tug twenty feet deep in the water, it will give a better rating than when only ten or five feet deep. If a skiff is used, the meter should be suspended from an outrigger, projecting two or three feet from the bow. If a weight is to be used in current measurements, it should be attached when the meter is rated, and a sheave in the end of the outrigger, and a reel in the skiff will be required to raise and lower it. The meter should be 2½ or 3 feet deep in the water. The skiff should be

hauled by a ¼ inch rope at a uniform and steady speed. The occupants of the skiff should sit perfectly still, so as not to rock the skiff the slightest amount There should be no wind, as it would cause a current in the water, and blow the skiff off the line it should travel parallel to the base line. The meter should be examined often to see if the insulated wires have become wound around the rod, so as to hold the meter out of line with the current, as this is likely to occur when backing the skiff or steam launch.

When rating the meter where there is a current, the direction taken by the launch must be reversed each time, and the successive up stream and down stream ratings must be computed in couples. In each couple the velocity should be made as near uniform as possible. The velocity in feet per second, and revolutions per second, are then computed. When the launch is moving with the current the velocity of movement through space is the velocity of the launch plus the velocity of the water, and when the launch is moving against the current, the velocity of movement through space is the velocity of the launch minus the velocity of the water. The half sum plus the half difference will be the greater, or the velocity of the launch, and the half sum minus the half difference will be the lesser, or the velocity of the water. Therefore, we take half the sum of the velocities and revolutions per second in each couple when computing the rating.

One method of rating both the Acoustic and other meters which the writer has used with very satisfactory results, is as follows: Take two soft steel wires about No. 24 gauge, and mark them every ten feet of their length by soldering a winding of very fine wire to them; one winding for ten feet, two windings for twenty feet, and so on. Make one wire about fifty feet long, and the other about 150 feet long. Wind the wires on two wooden wheels, which are about two and one-half inches in diamater, with flanges about five inches in diamater. Place the reels side by side, and give each a metal crank and shaft to wind them by. Each must have a spring pressing against it to retard its motion and keep the wires taut as they are running out. Pawls must be provided with knife edge points, which can be pushed into the wood to stop them from turning. Other springs hold the wires where they are running out, so they can not become loose on the reel. The reels, pawls and springs, should be supported by a wood frame and this should be screwed to the forward seat in the skiff. The observer sits just forward of the wheels and if he is rating the Acoustic meter, the rubber tube leads from the meter pipe to his ear. An assistant sits in the stern of the skiff, and his weight is needed to balance it. The wires are unreeled far enough to pass the end of the stern of the skiff, and to a stake which is driven firmly at the water's edge, and which has a nail driven half its length into the top. Rings of about No. 10 cotton thread are tied in eyes in the ends of the wires, and are passed over the nail in the stake. The skiff is hauled forward by a quarter-inch

cotton cord which leads across the pond, and another cord is attached to the stern, by which the skiff is prevented from running into the opposite shore. By pulling on the rope the skiff is started, and the wires are unreeled as the skiff moves along. When the observer hears the first click made by the hammer in the meter, he instantly starts the stop watch and presses a pawl into the wood of the reel which carries the short wire. This stops the turning of the reel and breaks the thread which connects the wire to the nail in the stake. When the meter wheel has made forty revolutions the observer will hear the third click, and at that instant he stops the watch and presses the second pawl into the second reel, which stops the long wire from running out and breaks the thread which attaches it to the nail in the stake. The length of each wire is then measured, using a steel tape from the last graduation on the wire to the reel. The difference in the length of the wires is the distance the skiff and meter traveled while the wheel was making forty revolutions, and the reading of the watch is the required time. Data should be obtained for very slow, medium and high velocities. Just before each trip is made the Acoustic meter wheel should be turned till it is about mid-way between two clicks, so that the first click will be heard by the observer before all of the short wire has run out. The amount of error in such a rating, supposing the skiff to move at the same velocity at the instant the first and last clicks are made, depends entirely on the time intervals used by the observer in starting and stopping the watch, and in stopping the reels after he hears the click of the meter. If he can make the time consumed by him to do this the same at the beginning as at the end of the run, all error will be eliminated.

When the data are reduced to revolutions of the meter wheel per second, and velocity in feet per second, and then plotted on cross-section paper, taking revolutions per second as abscissas and the velocities in feet per second as ordinates, the plotted points will lie in a curve. A line can best be drawn through these points by bending a true steel straight edge between three heavy weights till one side of it coincides with the points.

The rating curve of different forms of meters departs more or less from a straight line, depending upon the shape of the wheel. The point where the curve cuts the axis or ordinates, shows the friction of the wheel bearing. In the electric meters which have been most used on the Mississippi River this is about fifteen-one-hundredths of a foot per second, while for the Acoustic meter it is about four-one-hundredths of a foot per second. The reduction table should be made by scaling the plotted rating. One form of rating table devised by the writer, which reduces computation to a minimum, is made by forming a three column table and writing in the first column the times in seconds of one hundred revolutions of the meter wheel from twenty seconds to four hundred seconds, or more if very slow velocities are to be measured. Then compute

the revolutions per second corresponding to those times of one hundred revolutions and write them in the third column. Then from the plotted curve scale off the velocities in feet per second corresponding to those revolutions per second and write them in the second column. In using the meter, measure the time of one hundred revolutions and look in the table for the corresponding velocity. Meter rating tables are given in W. & L. E. Gurley's Manual of Engineers' Instruments.

The experience of the writer indicates that all the ratings of a meter when plotted on co-ordinate paper should give parallel curves. The distance these curves lie apart depends entirely upon the friction of the bearings of the meter wheel at the time the ratings were made. When a meter has been rated so that the curve has been accurately determined, all subsequent ratings should give the same curve or parallel ones, unless the meter has been altered in shape. All the different meters of one size and kind will usually give parallel rating curves. If the friction of the bearings only had changed the curves will lie apart from each other, but they will remain parallel. A slight change in the shape of a cup of the meter heel makes only a very slight change in the rating curve. Slight changes in the friction of the bearings make very slight changes in the intercept.

When computing the discharge, if the vertical velocity curve for that discharge section, has not been accurately determined the writer takes 96 per cent of the observed mid-depth velocity for the mean velocity for an open river. And for a river frozen over he takes 91 per cent. Each observed velocity should be multiplied by the cross section area extending from the point of observation half way to the next station on each side of it. To take the mean of two velocities and multiply the mean by the area between them is not as near correct as a low velocity may be given weight over too large an area, or a high velocity weight over too small an area, as would be the case when at one station the water was shallow and moving slow, and at the next station, one hundred feet away, it was deep and moving swift.

In order to do the best work with the current meter an engineer needs to have some experience, and needs to acquire some skill in the operation and care of the instruments used. He should be able to make all adjustments and repairs ever likely to be needed, or at least should know how to do so in order to know whether it is done correctly or not. When the writer has been stationed a long distance from a town he has had to stop in the middle of his observation and repair the stop watch, using a jack-knife and a brass pin for tools; and by putting in a piece of pine cut from the skiff, and a piece of rubber cut from his boot for a spring, the watch was set going and the work went on again.

DISCUSSION.

Mr. T. T. Johnston: Mr. Price's paper is of a good deal of interest. It has covered the process of gauging streams by the use of current meter, and to some extent with the rod float, but there are one or two thoughts that occur to my mind in connection with the subject of the paper presented by Mr. Price. One was his remark with regard to the changing in the rating of the meter. Within the last few months I have had occasion to observe a meter of a well known type that was adapted for measuring the flow of artesian wells. The meter was rated about five years ago, early in 1893, and was rated very carefully, and since that time has been used nearly every month, once each month in about sixty artesian wells. The general use, covering a period of not more than one day in each month for five years, would make sixty days' use of the meter. It might be estimated that its use was not more than would happen in half a year's use in gauging a stream.

At low velocities it had not changed very much; at velocities which would cause eight or ten revolutions per minute, at velocities which would occasion revolutions of 300 to 400 per minute, the rate had changed 30 or 40 per cent. That is indicative to some degree of the sensitiveness of the instrument to change in the rating.

Another thought occurred to me in connection with the propriety of using a current meter in gauging certain streams in preference to using rod floats. Take, for instance, the work done by the sanitary district in Chicago, where the work done came as the floods came and very irregularly. In one year we had no occasion to make any measurements at all, but when they were made, they had to be made in great numbers and with great rapidity, and no preparation could be made for them. Under circumstances of that kind the current meter hardly seemed to be a desirable instrument, because probably it may not be kept in condition, or may not be ready for immediate use; a bit of sand may be buried in it, or something like that; a thousand and one incidents by which the instrument is affected may exist. It seems to me that the rod float is far preferable to using the current meter in such a case, and so when occasional measurements have to be made for flow of streams where a meter might have to be borrowed and hastily put in place, it would be far preferable to use rod floats, in my opinion. That brings up the question of the relative merits of rod floats and current meters in measuring the velocity of currents. The rod floats, if used properly, necessarily embrace a large proportion of the depth of the stream. Corrections have been suggested for the reason that the floats do not cover the whole depth of the stream. Figures of correction do not amount to much in relation to any use to which the information derived can be put, and are perhaps an unnecessary refinement. The rod floats embrace the velocity of the current

from top to bottom. Mr. Price's conclusion that the floats might move properly from one direction to the other on account of the boiling of the stream, it seems to me, applies as much to the current meter as to the rod float. It is a question in my mind whether after all the rod float is not more satisfactory in measuring the mean velocity at any vertical element in the cross section of a stream.

President Noble: I would ask Mr. Johnston whether, in the second reading of the meter, the readings were at all points slower than at the original points.

Mr. Johnston: No, at the low velocities the rating did not seem to change to amount to anything that we could check up. It was at the higher velocity that its rating changed.

President Noble: And it was slower?

Mr. Johnston: Yes, the meter showed some signs of wear, and that seemed to be the effect of the wear. It was clean and in good condition otherwise. It simply shows that the current meter is quite a delicate instrument, and its ratings must be very carefully watched.

XXXVI

ON THE USE OF COKE BREEZE IN SEWAGE PURIFICATION.

By John W. Alvord, Mem. W. S. E.

Read May 18, 1898.

The science of the purification of sewage has been of late years co-existent with the development of specialized bacteriology. Nevertheless important advances were made before the biological feature of the chemical reaction was fully understood.

Thus intermittent filtration was developed in England in 1870 by Dr. Frankland for the Rivers Polution Commission, essentially as it is used and understood today, but it was not until 1877 that the researches of two French chemists. M. M Schloesing and Muntz, established the fact that nitrification in sewage and in soils is the result of the action of an organized ferment.

Warrington, in England, presented the results of his investigations on this subject to the British Society of Arts in 1882, but it was very slowly that the researches of Pasteur and others forced the conviction upon sanitarians that the biological initiative of nitrification was a primary requisite and not a resultant feature.

Following this conviction the experiments of the Massachusetts State Board of Health conclusively confirmed the presence of the nitrifying organism, and developed much valuable information as to its proper environment. These experiments were commenced in 1888 and have continued to the present time, their more valuable features being published in the report of 1890.

It is from this point in the history of sanitary science that I desire to review more in detail the development of what, for want of a better name, may be called "*Coarse Grain Filters*," and notice briefly the most recent ideas advanced and experiments made in regard to them.

The experiments of the Massachusetts State Board of Health did not leave the question of intermittent filtration upon land in a wholly satisfactory condition from a practical point of view, although the facts they demonstrated enabled the sanitarian to prescribe with far more exactness the rates of flow and kinds of soil for different quantities and qualities of sewage than he had ever been able to do before. The most favorable results, however, were obtained through certain sands, not always found where needed, and necessary in such large quantities and areas as to render intermittent filtration unaccessible as a method of sewage disposal for the cities of the larger class.

Thus, Chicago, investigating the question about this time, was obliged to estimate upon sand beds in Indiana, the extent and

area of which rendered their cost almost prohibitory in comparison with the dilution project afterwards adopted.

With the rates of flow of 20,000 to 60,000 gallons per acre per day, and not exceeding at any time upon the best soils 150,000 gallons, immense tracts of land are become necessary for cities of considerable size.

It was early noticed that the upper layer of such filter beds became relatively the most important portion, in that it propagated and kept in hardy condition a vastly greater number of colonies of the nitrifying organism than did the lower portion. In fact the greater part of the purification was observed to take place in the upper few inches of sand, and the superficial surface, or acreage, of such beds became of much more importance than their cubical contents.

In view of the more recent experiments it is believed that this difference is due largely to the inferior aeration which the lower portion of an intermittent filtration bed of the ordinary construction obtains.

The principle underlying soil purification is, that the liquid to be purified must be brought, before offensive decomposition has set in, into contact with wide diffusion at innumerable points with certain forms of nitrifying bacteria, in the presence of a sufficient supply of oxygen, and retained under such conditions a proper length of time for complete chemical change to be accomplished. This properly done the liquid is found to be purified.

Beds for intermittent filtration, as they have commonly been constructed, are not altogether so arranged as to bring this prinple into full play, and consequently while efficient within certain limits, are capable, if properly arranged, of affording much greater practical results, especially in the quantity dealt with.

As is usual when the time is ripe for a new step along any line of thought, this principle at once impressed itself upon several leading sanitarians and each proceeded to work it out in his own way.

One of our eminent engineers in this country began to develop the idea of artificial respiration and since 1894 has several plants in operation which force air upward or into the filter as the case may be. Excellent results are obtained and a large increase is gained in the quantity which can be purified.

The Massachusetts State Board of Health gives the results of its experiments along this line in the reports of 1895 and 1896.

They say: "The results obtained here and elsewhere with this method have been remarkable, but its practical operation depends upon obtaining the high efficiency of the coarse filters at reasonably low cost for the power used to supply the air current, and our experiments have tended to show that this cost is prohibitive. Our best results with this method gave a quantative efficiency of 248,000 gallons per acre per day, as calculated upon the total area of gravel and sand filters. This rate is no

greater than that at which newly constructed filters receiving the supernatent sewage from sedimentation or chemical precipitation can be operated, and it is reasonably certain that the sludge resulting from these methods can be taken care of more cheaply than it can be oxidized or burned up in the aerated gravel filters."

Another method of further developing aerated filters was one used by a private company who obtained the franchise for a city of considerable size, and erected a plant in accordance with their proprietary ideas, the main principle of which was the division of the filter into two halves, an upper and a lower, separated from each other by a considerable space, through which the sewage dropped in the form of rain. No extended series of analysis are obtainable as to the success of their experiment, but it is to be feared that results which were hoped for have not fully materialized.

It has remained for the London County Council to supplement the work of the Massachusetts State Board of Health, in the most successful manner yet attempted, in producing a coarse grain filter of high capacity and efficiency.

The Massachusetts experiments gave a clue to the line which should be followed. Their experimental filter of coarse gravel giving good efficiency with rapid rates of flow. This was cited at the time (1890) as conclusively proving the absence of any mechanical screening, and of illustrating the fact of bacterial action in the liquid film surrounding each particle of the filtration medium.

Acting on this suggestion Mr. Dibdin, chemist of the London County Council, constructed in 1891 four experimental filters filled respectively with pea ballast, coke breeze, burned clay, very coarse sand and polarite (a proprietary article).

These filters were worked intermittently for six weeks at average rates of 411,000 gallons per acre per day, the amount of purification effected being indicated by the reduction in oxidizable organic matter in solution as follows:

Burned ballast	43.3 per cent.
Sand	46.6 per cent.
Pea ballast	52.3 per cent.
Polarite (Proprietary)	61.6 per cent.
Coke breeze	62.2 per cent.

In his report at that time Mr. Dibdin says: "From the results obtained it appears that a considerable amount of purification could be effected by any filtering material, the desiderata evidently being porosity and consequent power of reabsorbing atmospheric oxygen. For foul waters sand appears too fine, while the burned ballast used was too coarse. Coke breeze seemed to unite the necessary qualifications and as it was also a cheap material it was selected for further trials on a larger scale."

In the second experiment a full acre filter was constructed at

the Crossness outfall of the London main drainage. The ground was leveled, underdrained and filled with three feet of coke breeze. The sewage was flowed on to the bed to the level of the surface as quickly as possible, allowed to remain standing full at least an hour, and then drawn off with the least delay. Working in this way the filter passed 1 1-6 million gallons (imperial) daily for six days, resting one day. This is equivalent to about 1,200,000 U. S. gallons daily, including time of rest. The purification obtained was 78 per cent based on the oxidizable matter, and the filtrates were said to be clean and sweet.

In Sutton, England, a similar series of preliminary experiments were undertaken, on a more elaborate scale, but with approximately similar results.

Upon them as a basis a coarse grain filter was constructed by filling one of the precipitation tanks, previously used for chemical process, with burned clay. The sewage passed from thence into a second tank filled with coke breeze. The operation of this plant commenced Feb. 11, 1897, and a rate of flow of 773,000 gallons per acre per day was obtained, rest period included. The results of 76 days operation in the first tank gave a reduction of 66 per cent in the oxidizable matter, the effluent from the entire plant showing a total reduction in the oxidizable matter of 86 5-10 per cent.

The solid matters held in suspension were reduced by the first tank 95 per cent and by the combined operation 99 6-10 per cent. The total quantity of suspended solid matters in the sewage, which were disposed of by the bacteria, was equal to 77 tons of sludge removed during the time of treatment, the average sewage having contained 54 5-10 grains per gallon. The fact that this quantity disappeared, without cost or nuisance is striking evidence of the capability of the process. At times these filters were worked up to a rate of nearly 3,000,000 gallons of sewage per acre per day. Such high rates checked the bacterial action, but did not permanently disable the filters

At Exeter, England, coke breeze filters 5 ft. in depth, on a similar plan have been in use since Aug. 1896, receiving sewage effluent much more concentrated than average American sewage. The rate of flow is about 666,000 gallons (imperial) per acre per day, inclusive of rest periods, and the purification obtained 75 per cent in oxidizable matter removed.

In all of these biological filters the operation is essentially different from ordinary sand filters of intermittent filtration as now practiced. Indeed, these biological filters are not filters at all in the sense in which the word is ordinarily used. Prof. Dibdin calls them "*Bacteria tanks.*" Another sanitarian proposes the name "*Digestors.*" "*Respirators*" and "*Aspirators*' have been proposed." *Biological Filters*" is not perhaps inappropriate, although the word filter is not apt. In these biological filters, so called then, the tank is filled with sewage, preferably from the top. It

stands full while the bacterial action takes place and is then emptied as quickly as possible. This is the breathing action. In emptying, the air must of necessity follow down into every part of the mass of the filter and complete the chemical action of oxidation. No other power is necessary to properly force the oxygen into the filter when the grain is sufficiently coarse. The biological action taking place on the surface of the grain it follows that the greater this surface the larger the field for action, but as the ordinary suspended matter in the sewage should not be allowed to clog the interstices, a size ranging from peas to chestnuts, dependent upon the amount of suspended matter carried in the sewage should be selected.

The character of the grain is essential, that material which will the most readily occlude atmospheric oxygen is preferred. A rough porous surface is better than a smooth one, such as wave-worn gravel. Coke has the quality in a high degree, although slag cinder and coal are not far behind.

Coke breeze being cheap and easily obtained seems to have advantages, although the selection of the material must be a question of local economy, it is evident that with a material of inferior efficiency a greater quantity and longer contract is necessary to make it economically equal to materials of the first rank.

Coke has the advantage that its porus structure holds large quantities of air in the interior of the grain. Experiments made by the writer show that immersion for a considerable time fails to fill the interior of the grain with liquid. A 24-hour immersion will result in wetting the surface only to the depth of one-eighth of an inch, leaving the air in the interior in place.

There is, therefore, a double surface of oxidation to act upon the sewage in the coarser grains, which cannot fail to add greatly to the efficiency of coke for this purpose.

Coke as a filtering material is not new to sewage purification works; but, so far as I am aware, it has never been used as a true biological filter until recently.

In Cheswick, England, coke filter beds were used to screen the effluent from chemical precipitation by an upward flow through beds 160 feet long, 8 to 10 feet wide, and 2 feet deep. About 2,500,000 gallons of effluent daily were passed through these beds by continuous flow. After three months of use the coke was removed and burned under the boilers, creating very offensive odors, which contributed to the disuse of the filters. These works were installed in 1879.

In Sheffield, England, coke breeze screens were installed in 1886 to filter the effluent from chemical precipitation. The estimated flow was about 10,000,000 gallons of sewage daily. The effluent passed into filter tanks, of which there were two for each precipitation tank. The filters were five feet in depth, and were so constructed that intermittent filtration could take place if desired, but no data can be found of rate of flow. The effluent from the filters was regarded as satisfactory.

At Bradford and Leeds, England, are similar works where the effluent from chemical precipitation has been screened through coke breeze. At Bradford the daily volume of flow is about 8,400,000 (1885), and the effluent from precipitation passes into thirty-four filtering tanks, one for each precipitation tank.

The continuous use of the filters does not permit of biological action, the filters act as mechanical screens.

Nevertheless some result is obtained, the quantity of organic matter held in solution by the effluent being reduced about one-fifth while the mineral matters are reduced about four-fifths.

At Reading, Pa., there has been in use a coke screen, so arranged that the sewage is passed downward through a layer one foot thick held upon a wire mesh. About 1,250,000 gallons per day are passed through this screen at the rate of 4,000 gallons per square foot per day, and with a reduction as stated by the Secretary of the Pennsylvania State Board of Health of about 40 per cent. of oxidizable matter. About 8,000 pounds of coke are used per week to charge the screen, and the removed coke is first dried in an oven and then burned under the boilers. A visit to this plant showed that the screen was but a mechanical apparatus for retaining solid matters from the sewage in the most ordinary way, and that its use was offensive and the odor from the burning coke was such as would probably cause the discontinuance of the use of the screen at an early day.

From these brief descriptions of coke breeze in purification works it is evident that all the use which has been made of this material previous to 1891 has been as a mechanical screen and without reference to its peculiar adaptability as a biological filtration material. We have already noted the commencement of its use as a true biological filter at Crossness in 1891, and it only remains to study the experiments made with it by the Massachussetts State Board of Health.

Filter No. 65, filled with coke breeze, was operated at the rate of about 300,000 gallons per acre per day, with a removal of 96 to 99½ per cent. of impurities (measured by albuminoid and bacteria) and it is stated that "The filter has disposed of the applied sewage easily and its effluent has been of a satisfactory quality."

No mention is made in the report of trials at higher rates of flow, with a smaller percentage of purification, which would be of great interest in view of the London, Exeter and Sutton results.

Filter No. 81 is also a coarse grain filter, with cinders as a filtering medium, and is operated by filling and emptying, as before described.

The sewage run into this filter was ordinary Lawrence sewage strained through coke. The report says: "The filter received sewage at the rate of 514,000 to 610,000 gallons per acre per day, with a purification of from 50 to 75½ per cent., the results showing less favorably for the cinder than for the coke."

Filter No. 22 A of coke breeze, 60 feet deep, was operated at

the rate of 600,000 gallons per acre per day, with a purification of 65½ to 86 per cent. This was with crude Lawrence sewage.

In general conclusion upon these experiments the report states: "When coke breeze can be obtained and the sewage given a preliminary treatment before sand filtration by being passed through this breeze at a high rate in gallons per acre per day, the organic matters in the sewage can be removed from the entire body of the sewage as completely as chemical precipitation removes them from the main body of the sewage."

The Massachusetts experiments do not seem to have obtained as high results in rate of flow as the English experiments.

TABLE II.—SHOWING THE RESULTS OF EXPERIMENTS WITH COARSE-GRAIN FILTERS AT LAWRENCE EXPERIMENT STATION, COMPILED IN PERCENTAGES, 1896.

Filter No. 65—Coke breeze 5′ deep. Rate of flow, 279,000 gallons per acre daily.

Entire Year of 1896.	Ammonia.		Nitrogen as		Oxygen consumed.	Bacteria per cubic centimeter.
	Free.	Albuminoid.	Nitrites.	Nitrates.		
Strained Sewage..	4.07	0.41			2.12	1,500,000
Effluent..........	0.51	0.38	2.49	0.204	0.15	11,127
Purification, per ct.	0.875	0.905			.93	.995

Filter No. 65—Coke breeze 5′ deep. Rate of flow, 300,000 gallons per acre daily.

Based on Last 5 Months of 1896.	Ammonia.		Nitrogen as		Oxygen consumed.	Bacteria per cubic centimeter.
	Free.	Albuminoid.	Nitrites.	Nitrates.		
Strained Sewage..	4.084	.440			2.21	1,605,800
Effluent	.266	.0366			0.15	6,552
Purification, per ct.		.965			.93	.999

Filter No. 81—Cinder 4.5′ deep. Rate of flow, 562,100 gallons per acre daily.

Entire Year of 1896.	Ammonia.		Nitrogen as		Oxygen consumed.	Bacteria per cubic centimeter.
	Free.	Albuminoid.	Nitrites.	Nitrates.		
Strained Sewage..	5.12	.545			2.92	2,476,500
Effluent	4.46	.27			1.04	606,400
Purification, per ct.		.505			.645	.755

Filter No. 22A—Coke breeze 5′ deep. Rate of flow, 360,000 gallons per acre daily.

January and February, 1896; filter destroyed in M'ch by freshet.	Ammonia.		Nitrogen as		Oxygen consumed.	Bacteria per cubic centimeter.
	Free.	Albuminoid.	Nitrites.	Nitrates.		
Crude Sewage....	4.13	0.685			3.23	
Effluent	1.243	0.096			1.12	164,150
Purification, per ct.	.70	0.86			0.655	

This is due probably to the fact that the high English rates have not been continuously tried at Lawrence. It will be noted in Mr. Dibdin's experiments at Crossness that the earlier rates of 500,000 gallons per acre per day gave practically the same results as the later rate of 1,000,000 gallons per acre per day on the same filter. This is shown in the following table III:

TABLE III.—SHOWING RESULTS OF ANALYSIS MADE BY MR. W. J. DIBDIN, CHEMIST TO THE LONDON COUNTY COUNCIL, ON THE EFFICIENCY OF A COKE BREEZE FILTER.

One acre of coke breeze 3′ deep.

Date.	Quantity of effluent passed daily per acre—average of 7 days.	Average oxygen absorb'd in 4 hours—grains per gallon.		Average Albuminoid Ammonia—grains per gallon.		Average Nitrogen as Nitrates—grains per gallon.		Average Purification, as determ'd by ox. abs'd.
		Effluent.	Filtrate.	Effluent.	Filtrate.	Effluent.	Filtrate.	Per cent.
1894.								
April 1 to June 9	500,000	4.096	0.856	0.416	0.095	0.1280	0.2378	.793
Aug. 3 to Nov. 9	600,000	3.608	0.730	0.396	0.113	0.0223	0.1414	.796
1894–95.								
Nov. 16 to M'h 2.	1,000,000	4.113	0.935	0.382	0.114	0.3956	0.6990	.775
1895.								
Ap'l 8 to Ap'l 20.	1,000,000	3.512	0.884	0.360	0.102	0.1431	0.770	.754
May 4 to Sept. 28	1,000,000	3.233	0.638					.807

It has been suggested that in the English experiments effluents from precipitation or septic tanks were used, while in the recent Lawrence experiments the sewage was only mechanically screened. That effluents from chemical precipitation are much more easily oxidized than are the suspended matters of crude sewage is well known. Precipitants, as ordinarily used, not only settle the suspended matters but partially dissolve them, so that they are more readily broken up by other processes. It will be observed that in the Massachusetts experiments crude Lawrence sewage is used upon a coarse grain filter with comparatively as good results as with the screened sewage, while among the English results is one at Sutton, where not only is crude sewage run immediately upon coarse grain filters but a particularly concentrated sewage,

containing suspended matter in much higher degree than normal American sewage.

The following table IV gives the results of the reduction of suspended matter:

TABLE IV.—SHOWING REMOVAL OF SUSPENDED MATTER IN ENGLISH COKE BREEZE FILTERS—ANALYSES BY PROF. DIBDIN.

Quantities expressed in grains per imperial gallon.

PLACE.	Time of operation.	Crude sewage.	After chem. precip. or septic proc.	After rough filtration.	Final effluent.
London .... (Crossness.)	4 Years	31	6.3		Trace
Exeter	10 Months	24.5	10.8		Trace
Sutton	6 Months	60		2.78	0.75

In view of these results we must believe that the English practice is wholly wrong or that lack of experiment at Lawrence of high rates of flow for long time are wanting. The latter supposition seems to be the most reasonable.

A review of the recent development of coarse grain biological filters would not be complete without some reference to the accounts recently published of coal slack filters which have been tried in Wolverhampton and Litchfield, England.

In the summer of 1897 Mr. Garfield, Manager of the Wolverhampton sewage works, together with Mr. E. W. T. Jones, public analyst for that town, carried out experiments with filters 5 feet in depth formed of coal slack sifted in layers of different degrees of fineness from ½ inch cubes at the bottom to dust at the top, the whole quantity except the bottom, 6 inches, passing through a 3-16 inch mesh, and this so fine as to be almost waste product at the mine.

Rates of flow of 1,000,000 gallons per day of effluent have been run upon such filters with a resulting purification on oxygen absorbed of 84 to 95 per cent.

Similar experimental filters have been laid down in Litchfield with equally good results. The effluent used seems to be from chemical precipitation tanks, but the Wolverhampton sewage being loaded with chemical refuse and the Litchfield sewage with brewery wastes, it is probable that, even though they are effluents, they are more concentrated than average crude American sewage.

It may now be inquired what are the practical results of this recent extension of our knowledge of biological filtration? In

A full account of these experiments may be found in a paper by Prof. A. Bostock Hill, M. D., of Birmingham, Eng., abstracted in the Municipal Eng. Mag. for Jan. and May 1898 Also notes from a paper read in Staffordshire, Eng., by Dr. Geo. Reid, noticed in the Eng. Record Vol. 31, No. 8, Page 164, July 24, 1897.

answer it can be safely affirmed that a wide field for successful application of artificial intermittent filtration in coarse grain filters has been opened up, which may include a class of larger cities that have been hitherto debarred from undertaking the effective solution of this problem. A mechanical screening should precede any such treatment, sufficient to remove paper and other fibrous matters which would clog the surface of the filter and are not readily oxidized. It is probable that finer screens than any now in use in sewage works will be necessary for this purpose. The refuse from these screens may be immediately burned in garbage crematories conveniently located and which may be prepared for consuming other city refuse of a like character.

Mr. Dibdin is now proposing to filter the entire effluent from the London precipitation works at Barking Creek and Crossness. 180,000,000 gallons of sewage daily would thus be treated upon 180 acres of coke breeze filters 3 feet in depth at a rate of 1,000-000 gallons per acre per day, inclusive of rest periods.

The city of Manchester now uses chemical precipitation for its sewage which amounts to 15,000,000 or 18,000,000 gallons daily. The effluent is emptied in the Manchester ship canal under protest.

A local committee, after a very thorough investigation, has reported in favor of further purifying this effluent by constructing thirty-seven acres of coarse grain filters or bacteria tanks, as they are called in England, at a cost of between $400,000 and $635,000. Land methods have been investigated, but their great cost has hitherto prevented any action being taken.

The city of Salford, on the opposite side of the river from Manchester, and really forming part of the same city, has investigated this form of purification with favorable results.

One cannot help speculating on the question of the application of this method to Chicago now fully committed to dilution methods.

This city is expending $35,000,000 for a drainage canal which will dilute the sewage of the city with the waters of the lake and pass the whole down the Mississippi valley. A further expenditure of several million dollars must be made for pumping stations, large flushing conduits, intercepting sewers and other changes in order to flush the branches of the river properly and convey all of the sewage into the drainage canal. Let us suppose in place of all this expenditure a system of intercepting sewers similar to those recently completed and now in use in Boston should be constructed in Chicago, capable of conveying the sewage or dry weather flow of the sewers to some central point well outside the city, presumably beyond Bridgeport. Placing the amount of dry weather sewage at 500,000,000 gallons in twenty-four hours the whole amount could be completely purified by double filtration through biological coke breeze filters of 1,000 acres in area and three feet deep, or 500 acres six feet deep, at the same rates as proposed by Mr. Dibdin for the London sewage.

A rough estimate of the cost of such a construction as compared with the drainage canal would show a total cost of $9,108,000. Compared with the $35,000,000 that the drainage canal will have cost by the time of its completion, this sum would not seem large, and with the dry weather flow of the sewage entirely removed from the river, all present nuisance would be obviated and the expensive dredging which has now to be annually undertaken to remove the settled sewage from its bottom would become unnecessary.

Under such conditions the present Fullerton avenue flushing conduit and the Bridgeport pumping station, with some modern pumping machinery, would give the river all the circulation necessary to keep it in an inoffensive condition.

In closing this paper I cannot refrain from somewhat extending the illustration of the lung as applied to the recent advances in sewage purification. The lung action or inbreathing of oxygen and out-breathing of resolved gases almost precisely describes the essential features of coarse grain filters. A further parallel between the human system and a properly arranged municipal service of water supply and sewerage is not inapt. In the human system the heart corresponds to the water works station, pumping the fresh blood through the arteries to collect the impurities of the tissues.

This may correspond to the system of distributing water mains of our modern city. The fouled blood having performed its function is returned through the veins, the sewers of the body, to the lungs for purification. It is at this point that the analogy ceases in the present state of practice. Nature in the human system by means of that marvelous mechanism the lungs completely and thoroughly purifies these wastes in the blood and sends it out to perform its function over again. In the municipality we have not permitted ourselves to think of this as possible, but turn away our fouled waters to be purified at hap-hazard in the nearest flowing stream; and where this is not accomplished by good luck—to contaminate the water supply of some community lower down upon its banks.

Such a city in turn reaches out with its fresh water intake for a flow that, let it be hoped has escaped the contamination of communities so fortunate as to be located above it.

The sanitarian of to-day is hard at work in the effort to perfect an apparatus similar to the lungs of the human system, that shall allow each community to purify its own wastes, rather than to inflict its neighbor with them.

It has already been demonstrated that this can be done efficiently, and it is now being shown that it can be done at reasonable cost

Effluents are now possible from carefully constructed and properly managed purification works, which are superior in character to the drinking water of many small towns.

The only difficulty has been to obtain these effuents with reasonable cost and care, and in the case of larger cities to obtain suitable land in sufficient quantity for effluents of any kind.

It is to be hoped and expected that the biological coke filter operated like a huge lung will constitute for the modern metropolis that lacking organ which will complete our control over our sanitary environment successfully.

DISCUSSION.

Mr. W. E. Williams: I would like to ask if there is any peculiar property in coke beyond its porosity and sharp corners, the porosity retaining the air and the sharp corners being the points upon which the suspended matter may cling, and whether any other material possessing those same mechanical qualities would not answer the same purpose?

Mr. Shields: The great advantage of coke is that it absorbs the oxygen, and that the sewage when it is admitted to the filtration tank, confines the air in the coke, thus giving two surfaces on which the oxygen acts.

Mr. Williams: Would not that also be true of any corresponding porous material?

Mr. Shields: Yes, it would be.

Mr. Wisner: The statement was made that the water was removed from the bacteria tank by drawing it off as rapidly as possible after it had stood for some hours, and also that they were in no sense filters. I wanted to ask if that water was drawn off from the surface, or by passing it through the material.

Mr. Shields: It is drawn off from the bottom, thus allowing the particles in the sewage to adhere themselves to the coke.

President Noble: In the filling of a tank of that kind, is more fluid admitted than sufficient to fill the interstices of the filter?

Mr. Shields: In the experiments which have been made by Mr. Dibdin, he filled the interstices of the coke bed with sewage and allowed it to stand for an hour or more, then the sewage was drawn off from the bottom, and the bed allowed to rest two or three hours to take in a new supply of air.

Mr. Condron: The paper states: "The sewage was flowed onto the bed to the level of the surface as quickly as possible, allowed to remain standing full at least an hour and then drawn off with the least delay," showing that the beds are supposed to have a bottom that will be impervious to water. I suppose a clay bottom is usually used.

Mr. Williams: I might add that where these works are desired to be established in this region, from some recent experiment which have been made in coking Illinois coal the coke might be made in this city, which would serve that purpose out of our own coal.

President Noble: Mr. Johnston, have you anything to say

about the comparison drawn in this paper between the cost of removing the Chicago sewage by the drainage canal and by the bacteria process.

Mr. Johnston: It seems to me that there has been nothing said in this paper about the cost of maintaining this sewage purification. It is said that there may be 1,000,000 gallons per acre purified; but the sludge is not destroyed there—that is, the stuff contained in what we call sewage—and before arriving at conclusions as to the relative cost of this method as compared with the drainage canal, that cost of maintenance should be considered. I was figuring that matter somewhat particularly with reference to chemical filtration, and find that, besides the mere cost of carting off the stuff that is excluded in a chemical filtration scheme, or such a scheme as this here proposed, there would be some trouble in finding a place to put the stuff, say three or four thousand tons a day, where sewage contains a great deal of material. Now, taking the water-carriage system, that is carried off without expense down the river, filling up the limits on either shore, creating new land.

Compared with London, I think that all the refuse may be taken and disposed of much more easily than would be the case in Chicago. There it may be taken out into the sea by scows and dumped; here it would have to be carried off in cars. Schemes of that kind would fall down in Chicago, and the expense, if capitalized, would far exceed the principal that is being expended on the drainage canal.

The matter of collecting sewers to bring the sewage to some particular point is a matter that does not enter, because the Chicago drainage canal is one of main drainage, and not one of local drainage.

Now, one other point which is an exceedingly important one, is that the effect of the drainage canal will be to keep the storm waters from going to Lake Michigan. The storm waters of Chicago, I believe, are easily as offensive as the ordinary sewage. Some day in the future, when the streets are properly swept every night and housewives do not throw out so much grease and so on, then the storm waters may not be so bad; but in the present condition they contain more matter—and that has been determined by actual test—than the ordinary dry-weather flow, and that stuff ought not to be permitted to go into Lake Michigan. Our storm water should be made to flow to the Mississippi, and as long as chemical or other filtrations do not take that into account, it does not occur to my mind how they constitute a satisfactory method of disposing of the city sewage.

CORRESPONDENCE.

Mr. Alvord: With reference to the first point raised by Mr. Johnston, it may be proper to state that the biological filter, so

far as observed, entirely consumes the organic matter in the sewage, leaving no sludge to be dealt with. It is quite evident from what has been said that foreign substances and coarser matters in the sewage should not pass on to the beds, but should be screened out and cremated.

The great feature of this method is that there is no sludge to care for. The organic wastes are converted into inoffensive gases and harmless mineral residue. As a result of the absence of sludge, it is apparent that the operating cost may be comparatively low. There is a large area of unit beds. You turn the sewage from one to the other by means of canals and gates. After a certain interval you empty them again. Obviously the cost of maintenance is ordinary labor to operate valves, and even this expense is avoided at Exeter by means of an ingenious arrangement by which the emptying and filling goes on automatically. Of course there must be efficient superintendence, a chemist to watch and guide operation, but there are no renewals or repairs, other than those ordinarily incident to the use of such a series of reservoirs.

Naturally it is quite difficult to compare the capitalized cost of such a system with the drainage canal, for the capitalized cost of the drainage canal is not the least difficult estimate of the two to make. From such figures as I have made, I am convinced, however, that the capitalized cost of the drainage canal is more than double that of such a system.

Certainly the operating expense of 500 acres of coke beds in which sewage is filled and emptied, and from which no resultant sludge is removed or renewals made, must be less than the maintenance of a canal twenty-eight miles long, flowing 300,000 to 600,000 cubic feet per minute. A rough estimate of the operating expense of the latter from so competent an authority as Mr. Johnston would be extremely interesting and valuable at this time.

The point raised by Mr. Johnston, that the storm water in Chicago is more foul than ordinary dry weather flow, from actual tests, is certainly interesting.

I think, however, this is not due to street washings, which are ordinarily intercepted and removed by the street catch basins, but rather to dry weather accumulation in the sewers themselves, which are flushed out by the storm water.

It would seem to me that overflows from an intercepting sewer system can be designed which will retain the largest portion of this suspended matter, leaving only diluted storm water to reach the river and the pumping works at Bridgeport.

But if there are certain times when the Illinois and Michigan Canal is overtaxed by the present pump and the current in the Chicago river reversed, I have never been able to understand how the drainage canal is to better this condition of affairs. The sudden precipitation of several inches of rainfall upon the 175

square miles of Chicago and the territory of the tributary water sheds, will hardly be carried away by the drainage canal. Possibly the conditions in the south branch may be bettered, but the current in the main river and the north branch may be easily diverted toward the lake by a surcharge of storm water much as it is under present conditions.

The influence of the winds and barometric changes, also operate to produce possible contamination of the lake. A drop of one foot in the lake level from these causes is quite common, and a fluctuation of two feet in fifteen or twenty minutes is by no means rare. What will the effect of such a drop in the lake level be upon the main river, the north branch and even a portion of the south branch? I confess I fail to see how the drainage canal is to be used at all times with entire safety in this respect. But there are so many debatable questions with reference to the sanitary aspects of the drainage canal that it is not wise to enter into them here. My reference to the matter was made solely by way of illustration. The main point intended to be brought out by this paper being that by more rapid methods of artificial intermittent filtration recently tried, large cities of Chicago's class, without available land for land methods of sewerage disposal, are not debarred from careful investigation of intermittent filtration.

XXXVII

OBSTRUCTIVE BRIDGES AND DOCKS IN THE CHICAGO RIVER.

By G. A. M. Liljencrantz, Mem. W. S. E.

Read June 1, 1898.

Having been requested to present some notes on the Chicago river and the various obstructions to navigation which are found therein, I shall treat this subject under three separate heads, viz:

1. The river as it is;
2. The river as it will be, and
3. The river as it might be.

THE RIVER AS IT IS.

It is well known to everybody that the Chicago river has been and is of enormous value to the commerce of the city, through its large and extensive lake traffic, which compares favorably with that of any of the largest cities in the country, and this expresses it even more modestly than need be, not to overstate the truth. But it should be remembered that, in a place of such rapid growth and progress as Chicago, that which appears great and ample one day has generally proved small and insufficient the next. The dimensions of the river some thirty years ago were ample for the commerce and traffic of that time. So were the bobtail one-horse street cars for the street traffic, and the jog trot of the old horse gave comparative satisfaction as to speed. Four and five story buildings were then considered commodious for stores and offices. In such matters as well as in numerous others —too many to here enumerate—the greatest advances have been made since, however. We now ride in electric and cable cars; sixteen and eighteen-story buildings are no longer a rarity, and we find several that are even higher. Thus has almost everything in the city been "kept up with the times"—except the river. To be sure, it has been improved. Miles of docks have been built, periodical dredging has been done; improved bridges built, many of which are of excellent design and furnished with the best and most modern equipment for maneuvering, but the question is: Has it also been "kept up with the times?" Has the improvement of the river been kept abreast with other improvements in this great and rapidly growing city? And another question which, in the writer's mind, is still more serious: Are existing conditions such as to admit of an improvement of the river that will be commensuate with a metropolis of three or four million inhabitants, as Chicago no doubt will be but a few decades hence?

For is not the growth of Chicago, at the present stage of development, similar to the coasting of a sled down an icy hill, in that *it can not be stopped?* When studying the conditions we find much cause for discouragement. Fig. 389.

The improvement of the river for the purposes of navigation may be considered as of two different kinds or classes, which I may be permitted to term, respectively, the vertical and the horizontal improvement, the former called for by increased draft of vessels, the latter by the constantly increasing horizontal dimensions of the craft of modern times. Thus, the vertical improvement aims at securing a depth of channel sufficient for the passage of modern lake vessels at this port. Increased depth has been secured to some extent by occasional dredging, but it is again regularly decreased by the unceasing deposits from the numerous sewers emptying into both branches of the river, as well as by constant sweeping and dumping of refuse in various ways into the channel, requiring frequent redredging. But this *removable* material forms the least serious obstacle in the way of the vertical improvement. Not less than three tunnels cross the river, with their crowns at an elevation which, at the time they were built, allowed sufficient draft for the navigation of that day, but which now form the gravest obstructions to the much larger vessels of deeper draft of the present time; and I wish to repeat a remark I made at a meeting of this society in 1894, when a paper on the last built of these tunnels, the one at Van Buren street allowing only 18 feet draft of vessels, was read, viz: "The time will come, and before many years have past, when these tunnels must be lowered, if Chicago is to remain at the head among the lake ports."

These tunnels, if allowed to remain, limit the extent of the vertical improvement, of which more will be said under the next heading.

Docks are frequently built with more consideration as to cheapness in first cost than to future needs and are thus made only of strength enough for the existing depth of water, and are accordingly subject to undermining whenever the channel is considerably deepened. An extensive vertical improvement, even if the obstructive tunnels did not exist, would accordingly involve great expense to individual owners, in addition to the direct improvement by dredging, and to make such improvement practically permanent it will be necessary to dispose of the sewage by a different method from that now employed, or provide for continuous maintenance by dredging.

Let us next look at the difficulties we encounter in planning a horizontal improvement. Vessels of even the greatest dimensions in use until about 1890, and which still constitute the great part of the lake fleet, easily pass any part of the navigable river, but some of those built within the last few years find it impracticable to enter either of the branches of the river, or, loaded, to pass the first of the "artificially constructed

reefs, so to speak, the LaSalle street tunnel. The manner in which a long vessel has to move to make this passage possible is illustrated on the sketch marked "A-2," Fig. 390, showing tne river between Clark and Wells streets, with the tunnel half way between.* The available channel is here in the middle ot the stream. A vessel with 48 feet beam and 432 feet long (which is the length of the longest boat now navigating the lakes) is on that sketch represented as coming through the north draw of Clark street bridge, turning to the deeper channel in the middle, over the tunnel. It is compelled to proceed thence across to the south draw of the bridge at Wells street, because the turn to the north draw of that bridge is practically impossible, for there is only 500 feet between the two bridges, and the center channel has a depth of seventeen feet at low-water over the restricted width of only 62 feet on the line of center piers of bridges. The cross-sections on sketch "A-3", Fig. 391, will further illustrate this deplorable condition.

The principal obstructions along the two branches of the river are shown on other sketches accompanying these notes, by representing thereon the horizontal contours of a vessel of the dimensions mentioned, attempting to make a trip up the river, and meeting with the several obstructions on its passage. Thus, the sketch "A-4", Fig. 392, shows the narrow draws of Randolph, Washington and Madison street bridges, the chief obstruction of the first of these being, however, the clumps of piles at the west abutment. Sketch "A-5", Fig. 373, shows the bridges at Taylor and Twelfth streets, with the intermediate Wisconsin Central Railroad bridge. The vessel can pass through the east draw of the railroad bridge but through none of the other draws of these bridges. The dock south of Twelfth street bridge would prevent the passage also even if the east draw of this bridge were passable. The Cana street bridge, shown on sketch "A-6," Fig. 394, has a cente draw and would admit the passage of the long vessel wer it not for the obstructive dock to the north and west of the bridge At Twenty-Second street, sketch "A-7," Fig. 395, both the draw are too narrow. The Chicago and Alton R. R. bridge, North o Archer Avenue, sketch "A-8", Fig. 396, is a striking example c how some bridges are constructed without the least regard for th demands of navigation. Too narrow are also the draws of th three bridges, placed in close proximity at Kinzie street, in th north branch of the river, as well as at Indiana street bridge, all c which are shown on sketch "A-9", Fig. 397. Nothing larger tha a tug can pass the east draws of the first named three bridge which, in fact, had never even been dredged until in April of th year. At Division Street bridge neither draw can be used, n can those of the North Avenue bridge, shown on sketch "A-10 Fig. 398, by such large vessels.

* The sketches illustrating the conditions of the river, and accompanying this paper, w copied from those accompanying the report of Major W. L. Marshall, Corps of Engineers, Chief of Engineers, U. S. Army, for the fiscal year ending June 30, 1897.

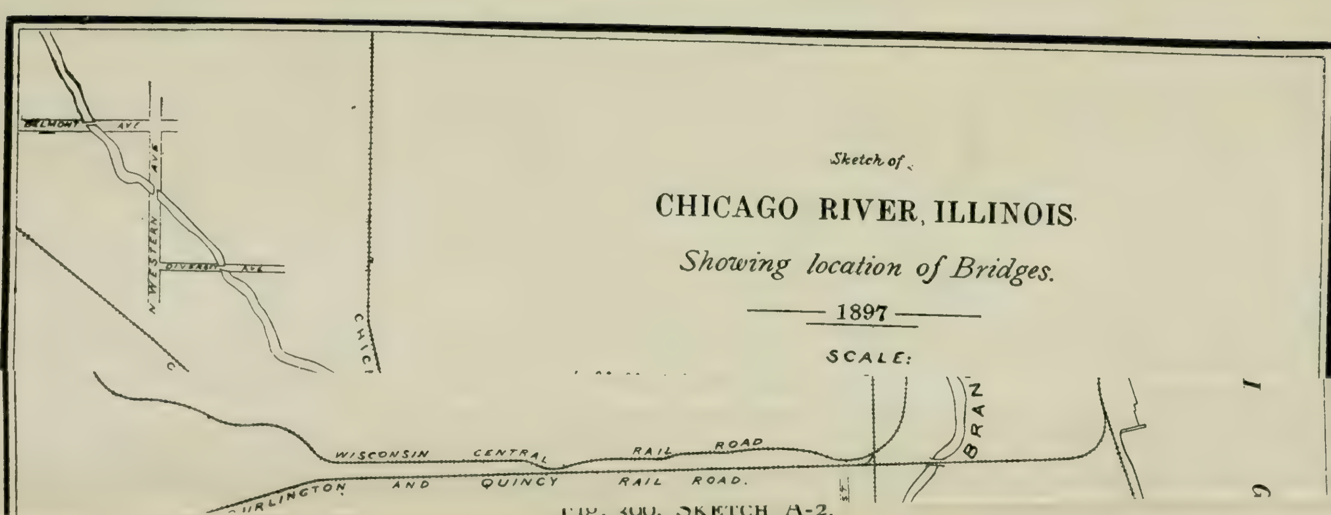
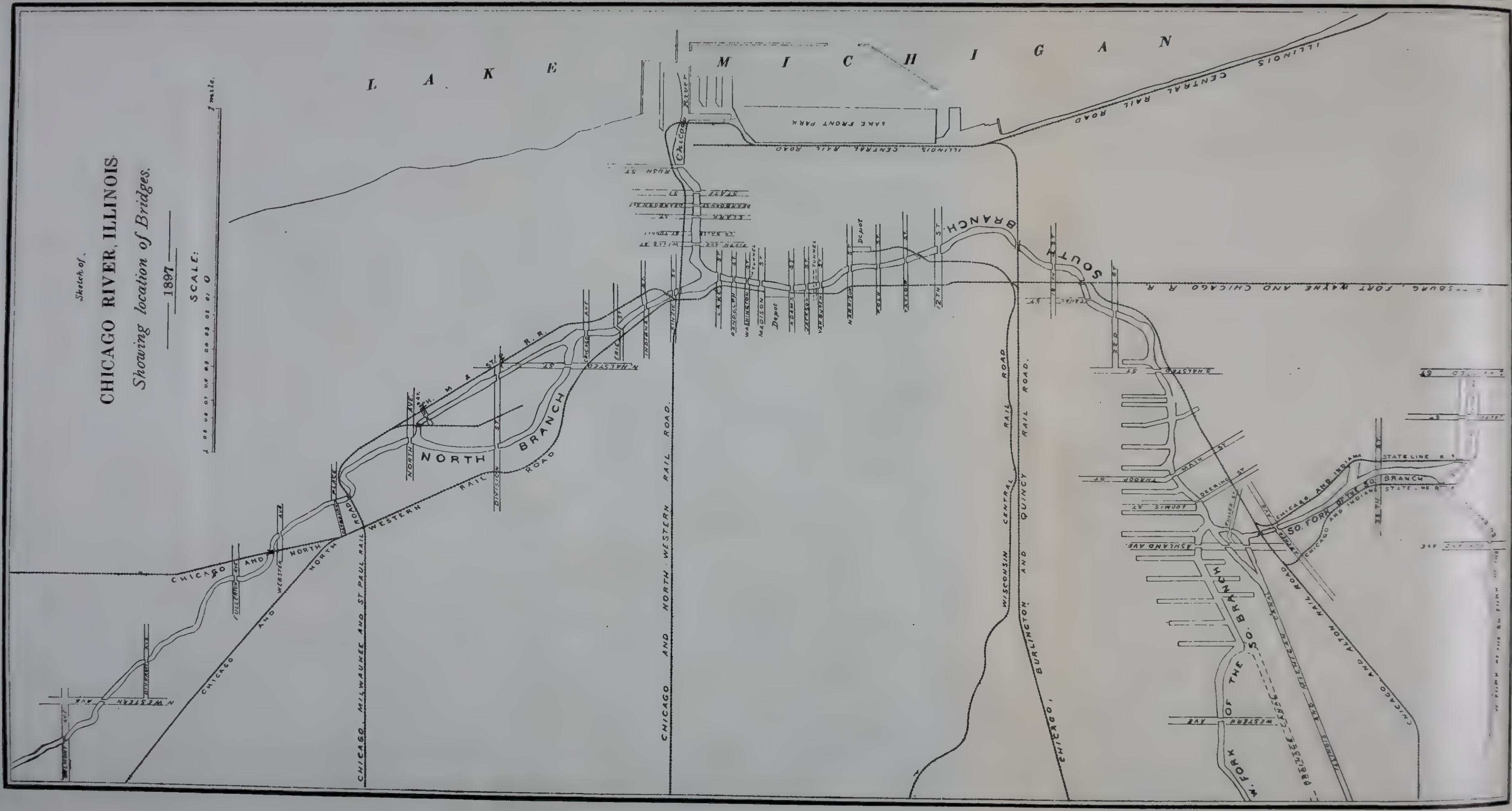


Fig. 390, Sketch A-2.

FIG. 389. L

FIG. 389. LILJENCRANTZ—OBSTRUCTIVE BRIDGES AND DOCKS IN THE CHICAGO R...



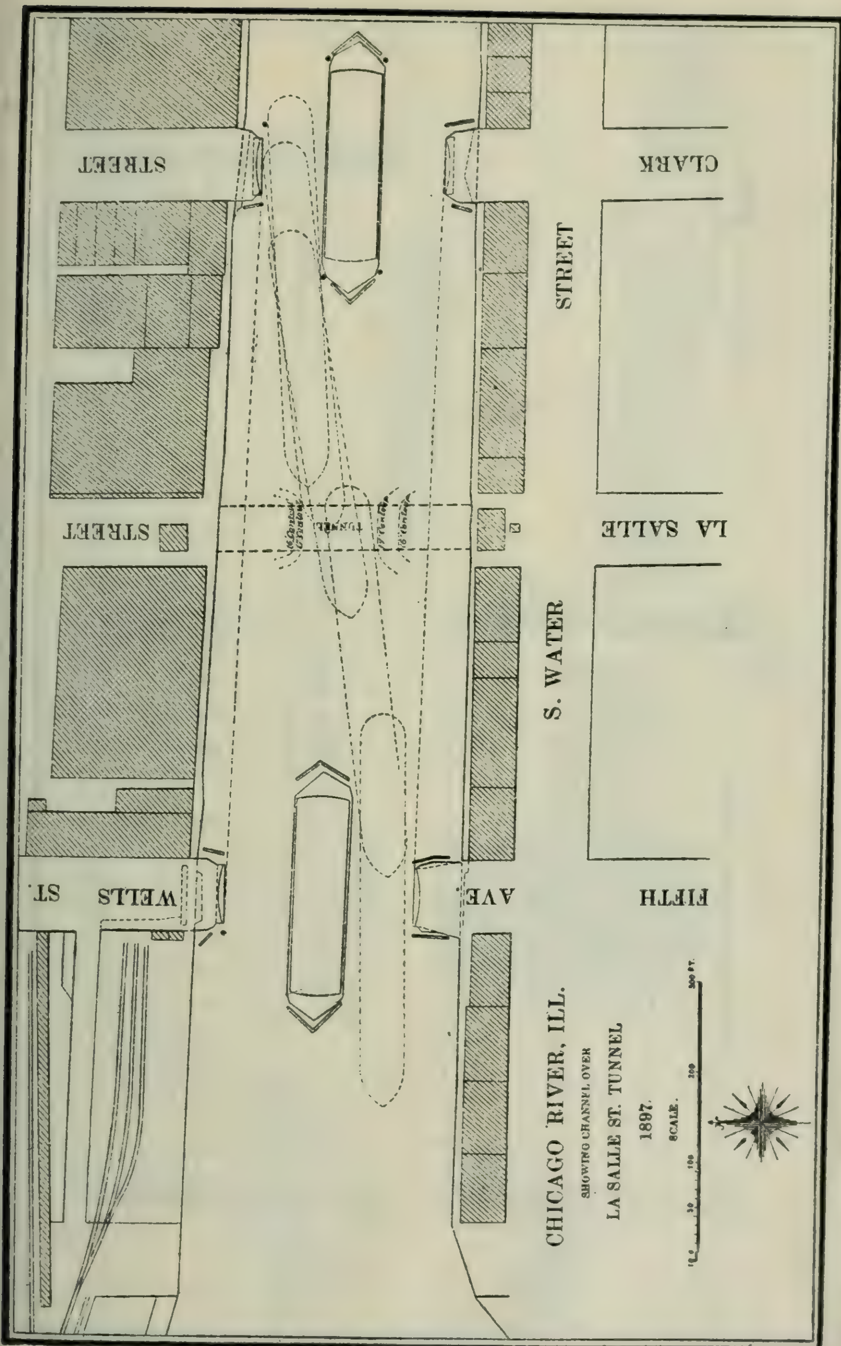


Fig. 390, Sketch A-2.

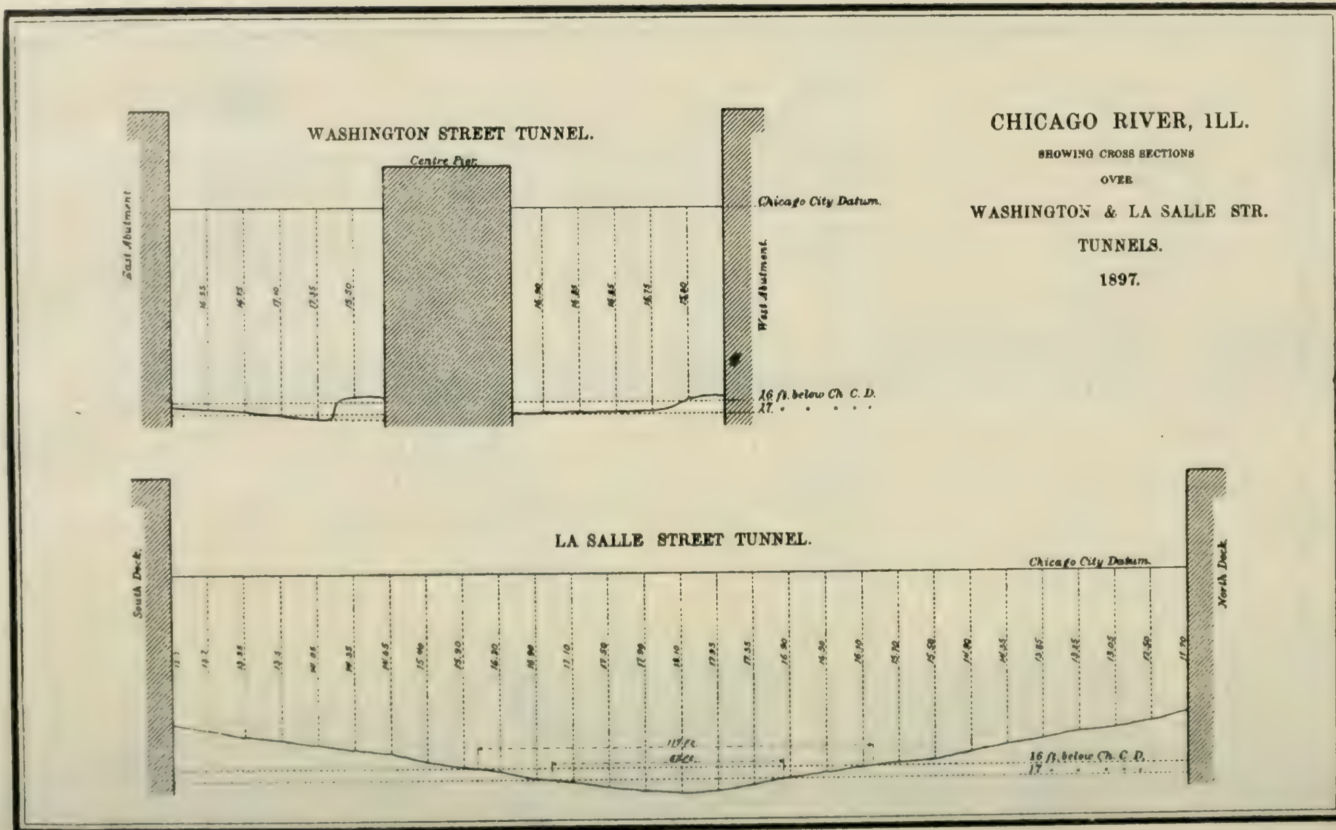


Fig. 391, Sketch A-3.

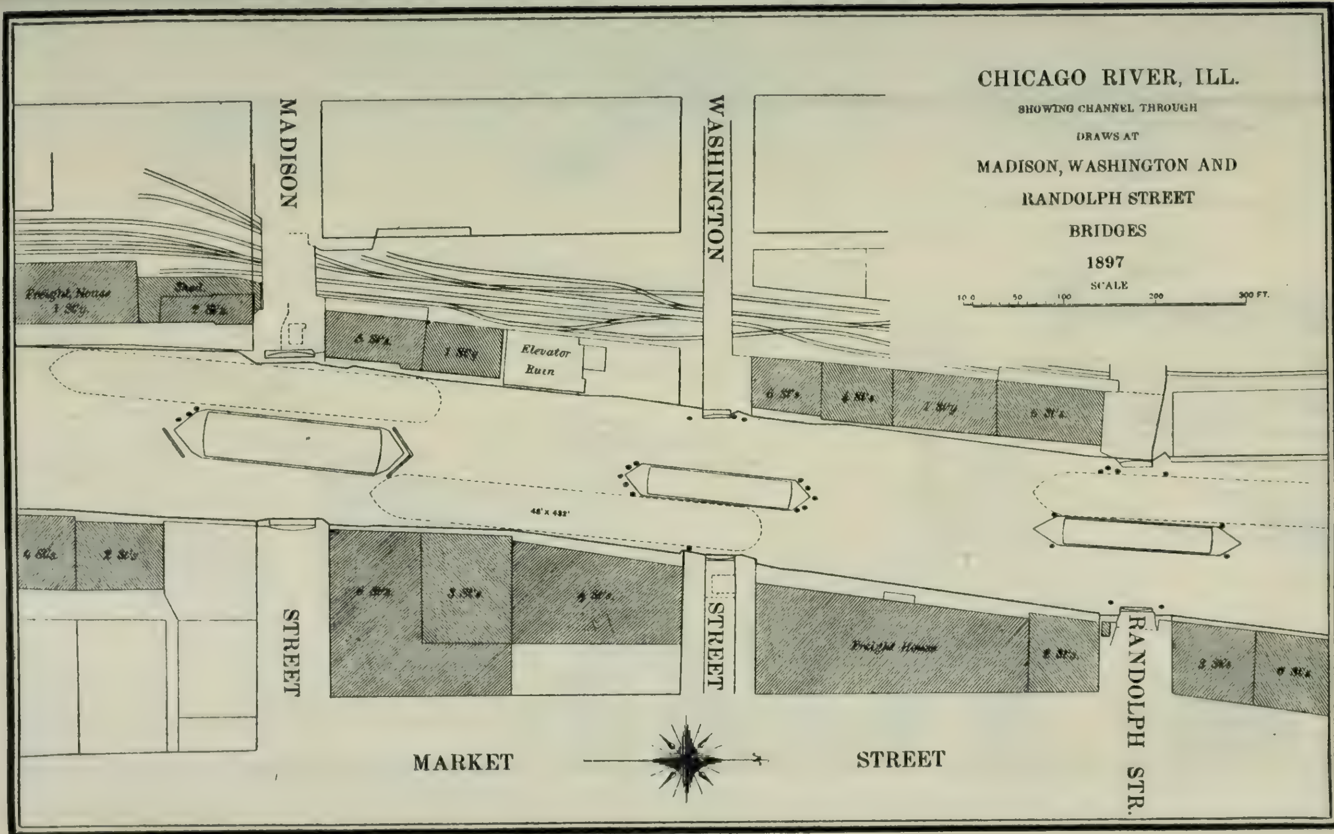


Fig. 392, Sketch A-4.

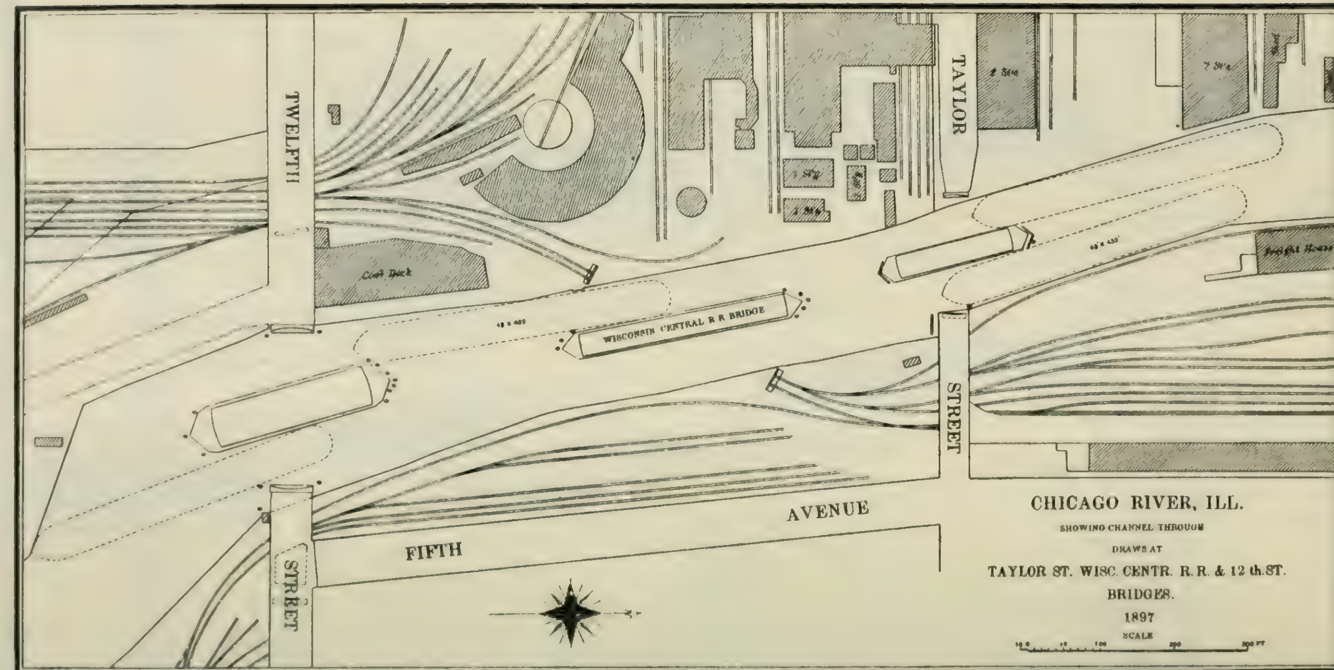


Fig. 393, Sketch A-5.

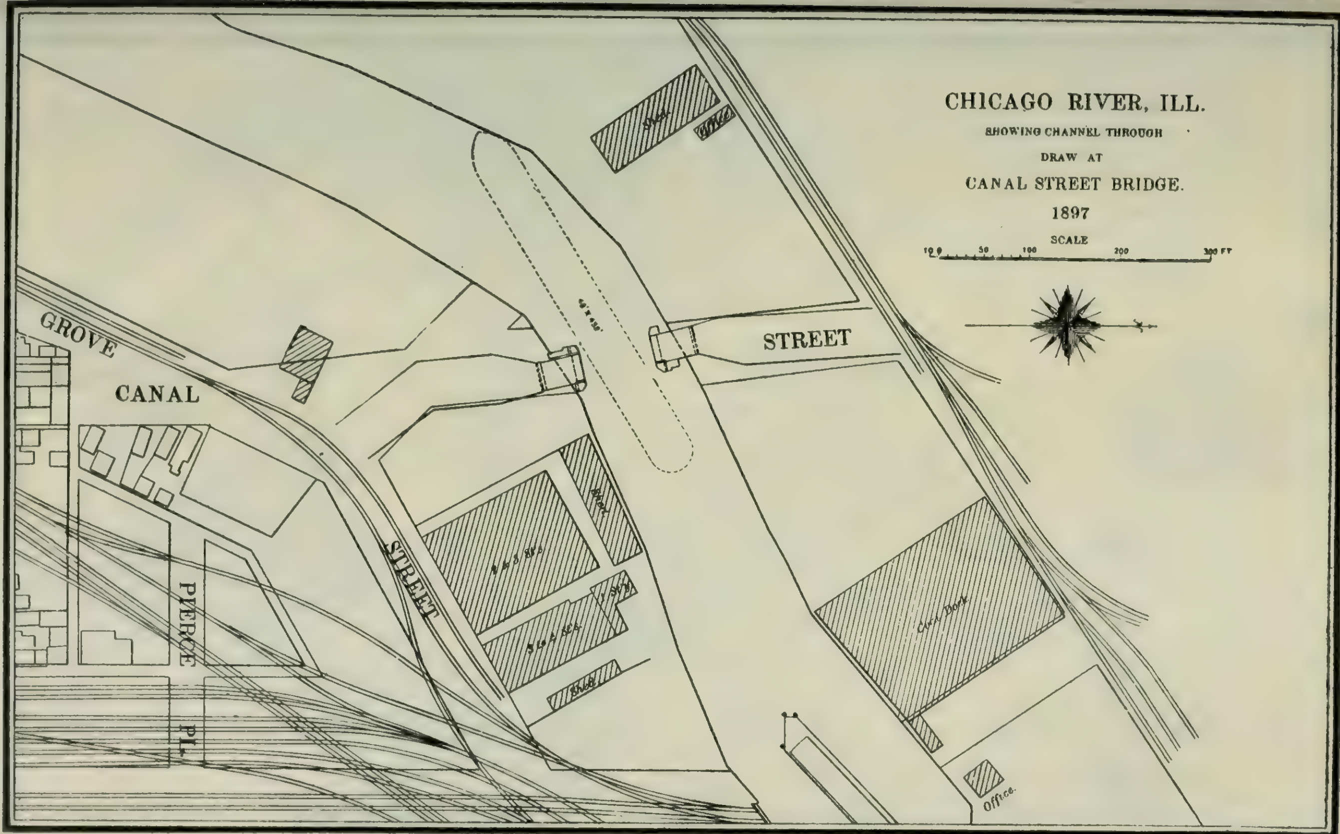


Fig. 394, Sketch A-6.

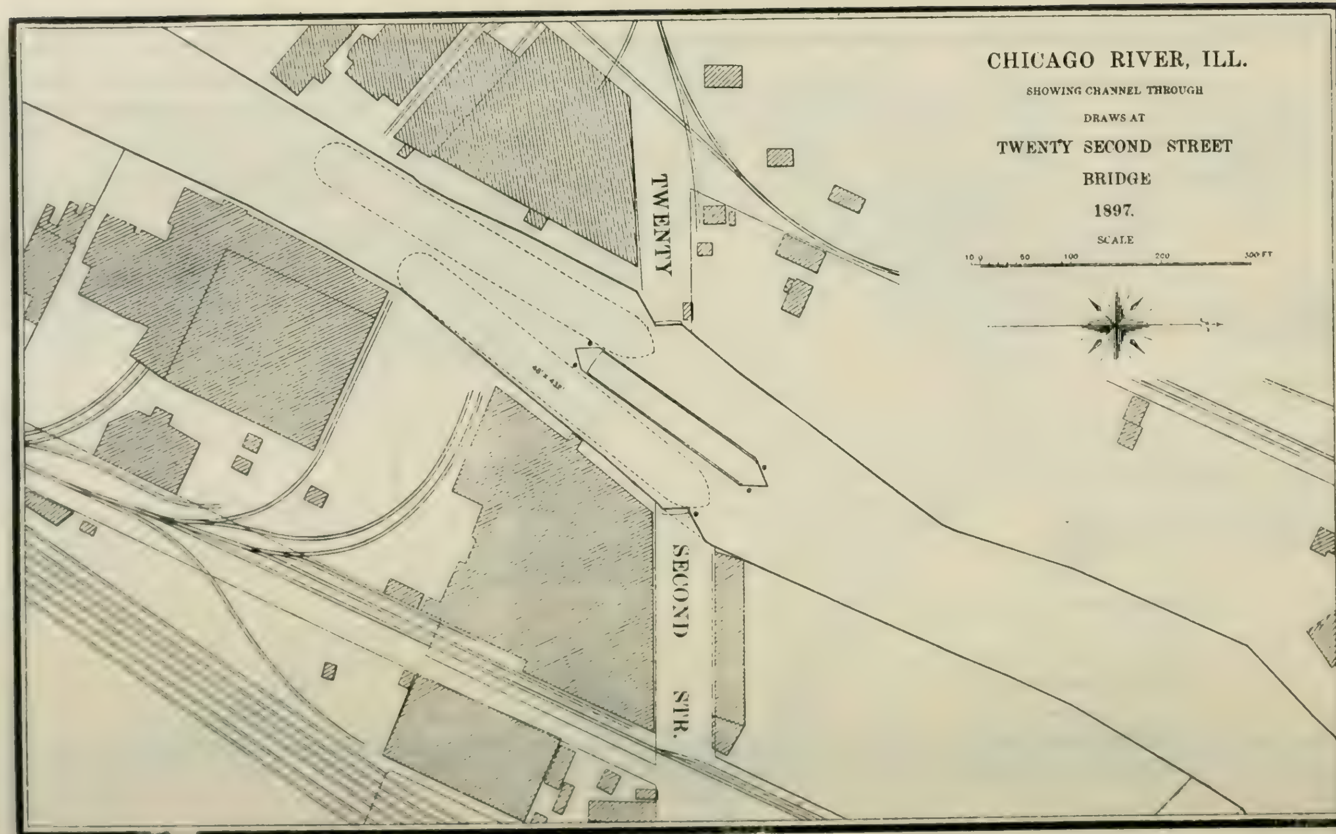


Fig. 395, Sketch A-7.

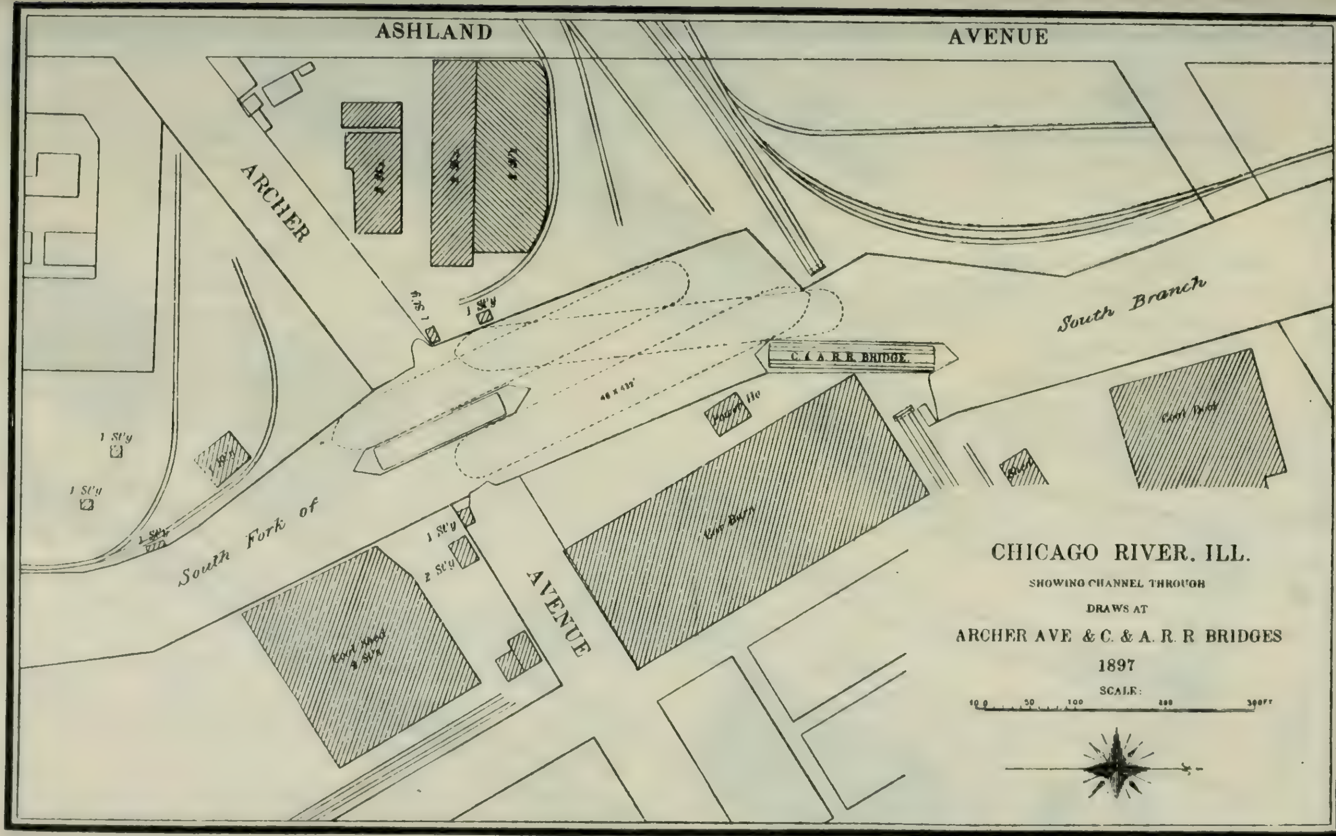


Fig. 396, Sketch A-8.

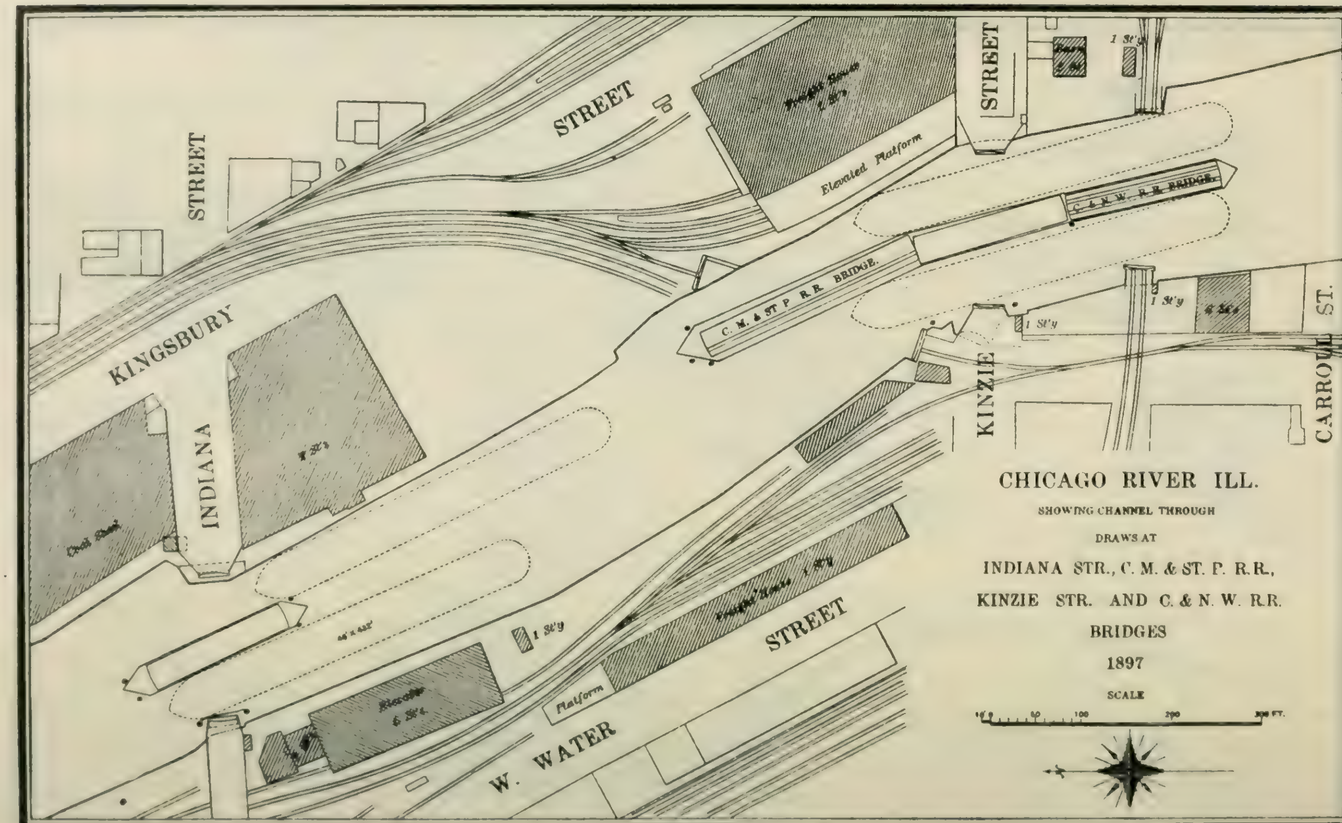


Fig. 397, Sketch A-9.

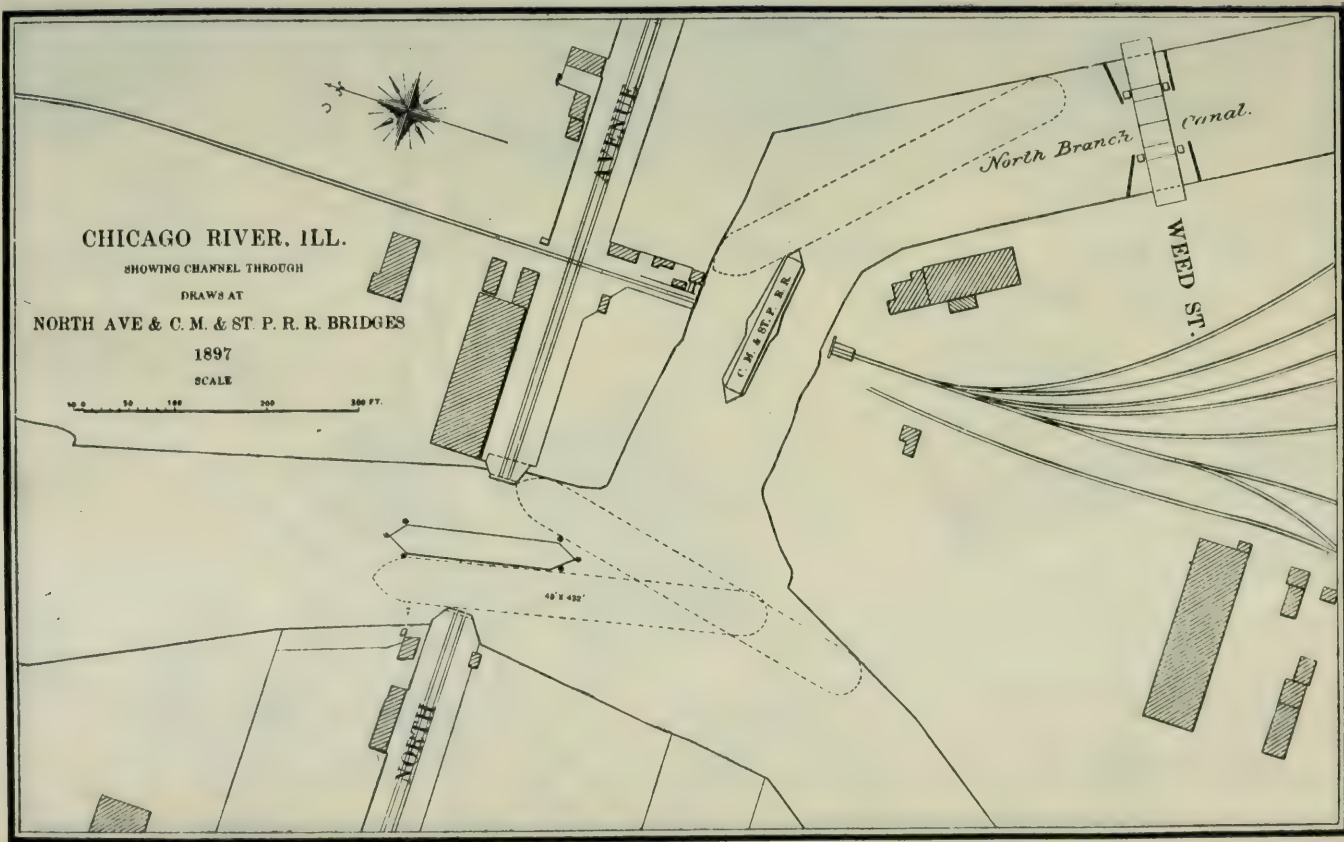


Fig. 398, SKETCH A-10.

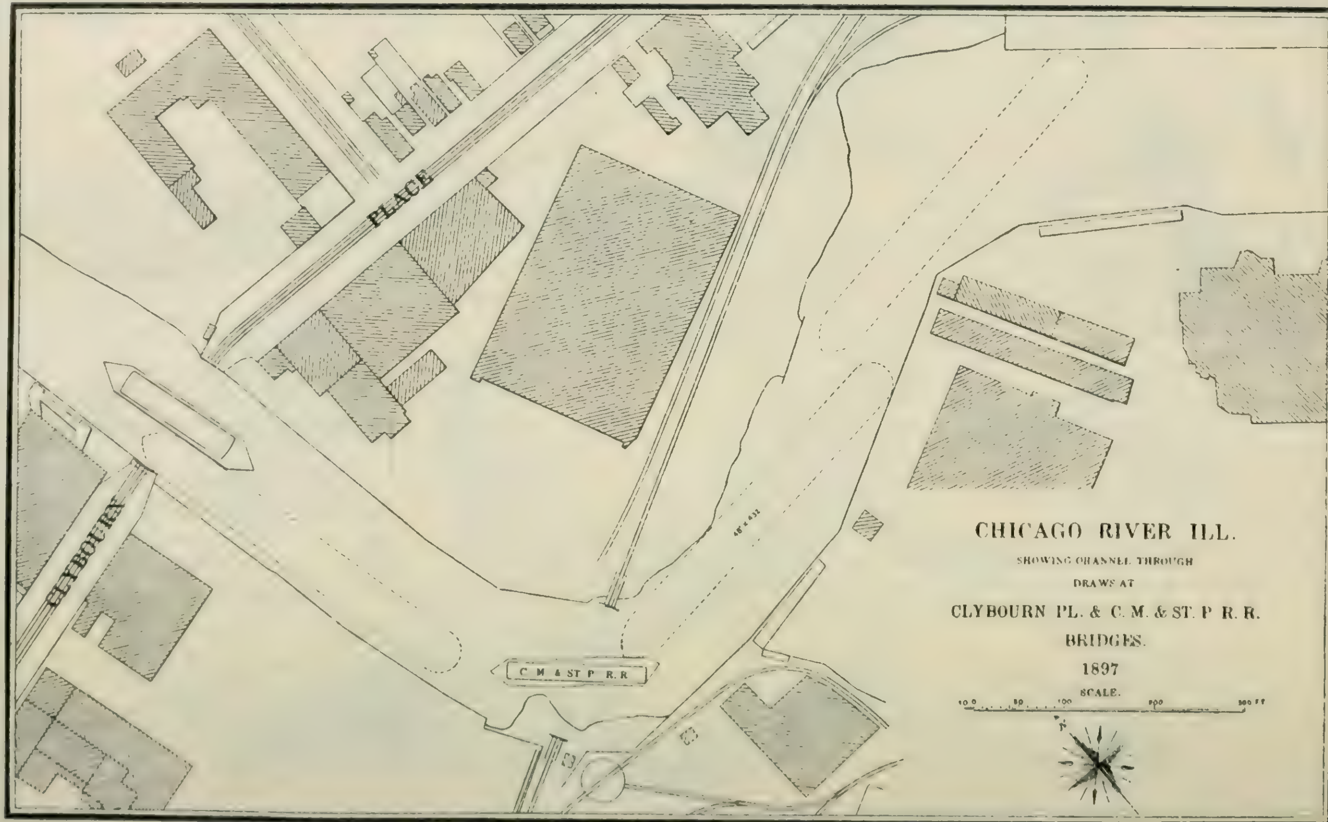


Fig. 399, Sketch A-11.

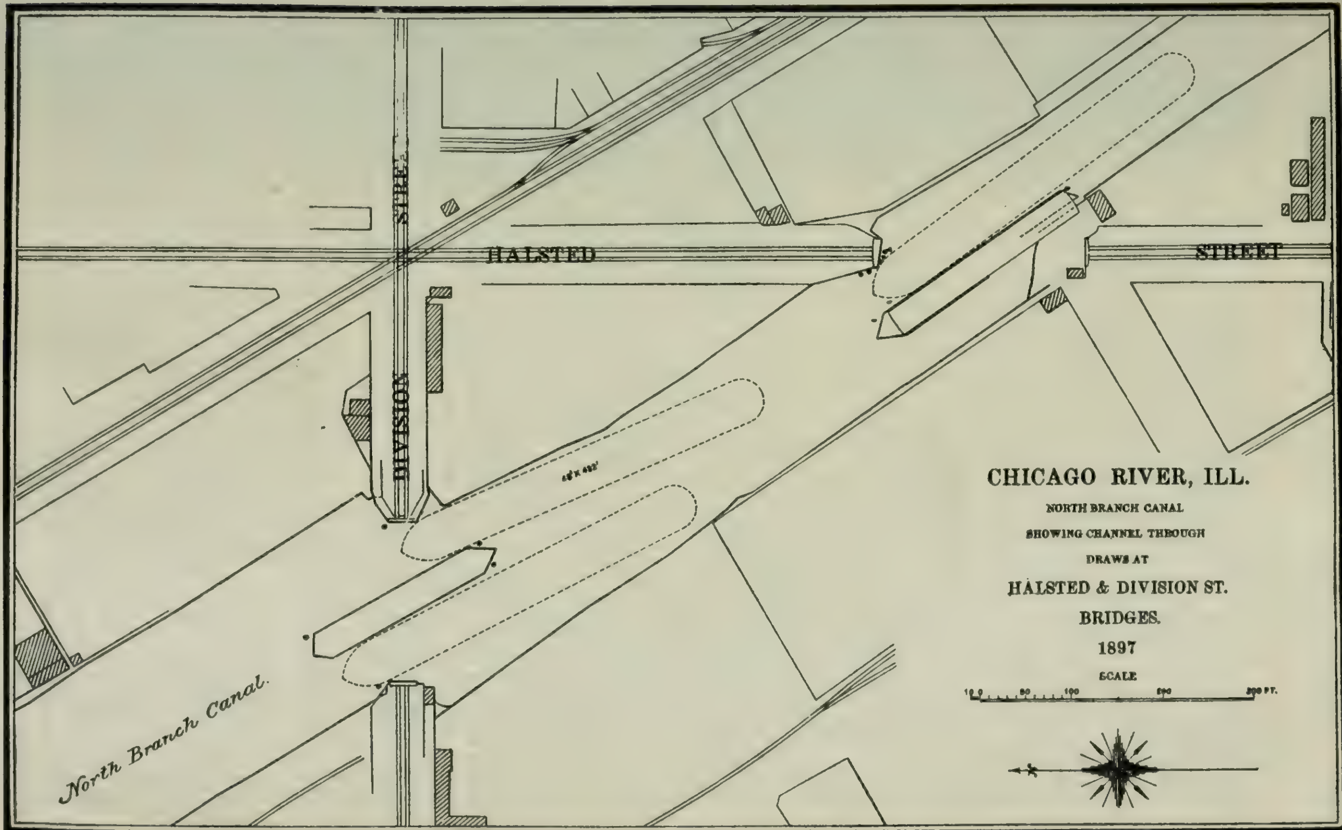


Fig. 400, SKETCH A-12.

One of the worst places on the north branch is the sharp bend forming an S-curve at the crossing of the M. & St. Paul Railroad bridge, south of Clybourn Place, sketch "A-11", Fig. 399, and nothing but the most radical alterations can make this part of the river, or that above, accessible to vessels of the type here represented, and it is therefore thought unnecessary to occupy more time and space in describing the obstructions found above this place, which are generally equally bad, and some perhaps even worse, and I will only mention one more to show the condition on the so-called North Branch Canal, east of Goose Island, where similar conditions exist, as shown on sketch "A-12," Fig. 400.

It can hardly be denied that the obstructions now described will have a tendency to discourage an attempt at making the river what it ought to be, to properly accommodate such an extensive and important navigation as should be provided for here, and still they are not the worst places found. These are described under the next or second heading.

The chief reason for the deplorable condition of the river, as regards its many obstructions, I consider to be the total absence of any well defined system of improvement, by way of legally established dock, or channel lines. Accordingly, the owners of water front along the river seem to have built their docks with the sole consideration for their own individual advantage, in such manner as to make as much land as possible, out of what should properly be the channel, apparently in utter disregard of the demands of navigation. Dock lines have been established, to be sure, in detached places, but, as far as I have been able to discover, not in conformity to any general system. In June, 1869, or twenty-nine years ago, there were established, by an ordinance passed on the 11th of that month, certain dock lines along a portion of the south branch. Provisions were made in this ordinance for necessary assessments to pay for the condemnation and purchase of land, required to comply with the terms of this document, but nothing further has been done in the matter, and numerous docks have since that time been constructed without the least regard to the dock lines so established, judging by the conditions now existing.

I would like to have it understood that I do not pretend to criticise or blame any individual for this condition of things. I only state the facts as I have found them, or as they have appeared to me; and no one person could well be considered as responsible, when there never has been any specific system or plan of improvement to carry out, and when the controlling powers change every two years, in which short period it is hardly possible for the incumbent to become familiar with a greater portion, much less with all of the multifarious needs of a city of the size of ours.

2. CHICAGO RIVER AS IT WILL BE.

By an act of congress of June 3, 1896, making an appropriation of $50,000 for improving the Chicago river "from its mouth to the stock yards on the south branch and to Belmont avenue on the north branch as far as may be permitted by existing docks and wharves," the work of improving this river by the United States government was inaugurated.

The only work that could be done, however, in compliance with the wording of the bill, was that which has hereinbefore been termed the vertical improvement, or dredging. Bids were advertised for and received, and contracts let for the execution of this work, which commenced in November, 1896. The project approved by the Secretary of War contemplates the deepening of the channel to seventeen feet below the city datum, the bill providing for dredging "to admit passage by vessels drawing sixteen feet of water." The existence of the tunnels would make a greater depth useless.

The work of dredging has been done from the mouth to the stock yards in the south branch, and a part thereof has been redredged, viz: From the south limits back to Twelfth street, and this work is now nearing completion towards the harbor. In the north branch the work has been done from the junction to Fullerton avenue, and when the northerly limit is reached, the whole of that branch will also be re-dredged.

Up to May 1, of this year there have been removed from the main and south branches, in round numbers, 540,000 cubic yards and from the north branch 658,000 cubic yards, or a total of 1,198,000 cubic yards. The sum of $113,000 was appropriated in a later act of congress, for the completion of this part of the river improvement, and authority was by this later act also granted for entering into contracts for work in the line of the horizontal improvement, such work to be limited by the sum provided for that purpose, to-wit: $700,000, including the amount required for the dredging. This work is thus confined to the removal of only the most obstructive of the many protruding dock corners.

The greatest obstructions to navigation are the tunnels and bridges, which are corporate property, and it is questionable whether the Government would ever consider the navigation in the river so necessary to the general commerce of the nation to condemn such valuable property, and either to compel the removal of the obstructions caused thereby, at the expense of the owners thereof, as can be done under existing laws, or to undertake the enormous expense of rebuilding or remodeling the structures at the expense of the public treasury.

To decide upon a plan of improvement, which will furnish the greatest relief to navigation, authorized by the bill, and at the same time keep the cost within the prescribed limits, a study was made, on the maps, of the various corners and bends in the river

to learn to what extent these would interfere with the passage of a vessel of the type described. The vessel was represented by a pasteboard model made to the same scale as the map. In this manner the most obstructive dock corners were selected and improvement of these places recommended, consisting in the removal of a sufficient amount of the protruding land to facilitate the passage of the largest vessel.

The places so selected are as follows: In the south branch, going southward, the first place to receive attention is near Eighteenth street bridge, sketch "B-1", Fig. 401. The east draw of this cannot be used by the large vessel and, moreover, cannot be made passable, owing to the sharp bend in the east dock at this place. The west draw can and will be so made, by the removal of 4,750 square feet on the north side of the bridge and 11,366 square feet on the south, as indicated on the sketch. The latter cut is to be regretted, as it takes off a valuable portion of a coal yard, but it is the only way of relieving this place, without exchanging the bridge for a center channel bridge, which cannot be done by the government. The next place is at the so called "Collision Bend," some 700 feet east of Halsted street bridge, sketch "B-2", Fig. 402, where 15,965 square feet have already been removed by the sanitary district and 7,702 square feet are proposed to be removed by the government. The name of this place is a brief but fair intimation of the conditions here. From the dock at the foot of Fisk street, a tract containing 12,054 square feet is to be cut off. At Throop or Main street bridge, sketch "B-3", Fig. 403, a piece of land containing 10,268 square feet is to be removed from the Gas Co.'s property south of the river and 9,294 square feet from the land north of the river, both east of the bridge. This latter cut is to be extended west of the street by the sanitary district, which authority, I believe, also intend to substitute a new and larger bridge for the present one. At the junction of the south and west forks of the south branch, sketch "B-4", Fig. 404, an area of 9,144 square feet will be taken off to enable vessels to turn around and pass from one of the forks to the other. Through this west fork the river is to be connected with the Drainage Canal. Between Hickory and Fuller streets, on the south fork, are docks constructed far outside of the "established dock lines," which docks form a very bad obstruction to boats going through the west draw of Fuller street bridge, and make a passage through the east draw impossible, except by short tugs or row-boats. The proposed removal of 6,988 square feet will very much improve this place, but not less than 22,600 square feet are actually located on waterside of the said "established dock-line," between the streets just named. Sketch "B-5", Fig. 405, shows the Illinois Steel Company's property, the north part of which forms an obstruction to the passage of vessels through the west draw of Archer avenue bridge, and is to be removed. The river is furthermore very narrow all along this property and in all 18,790 square feet are to be taken

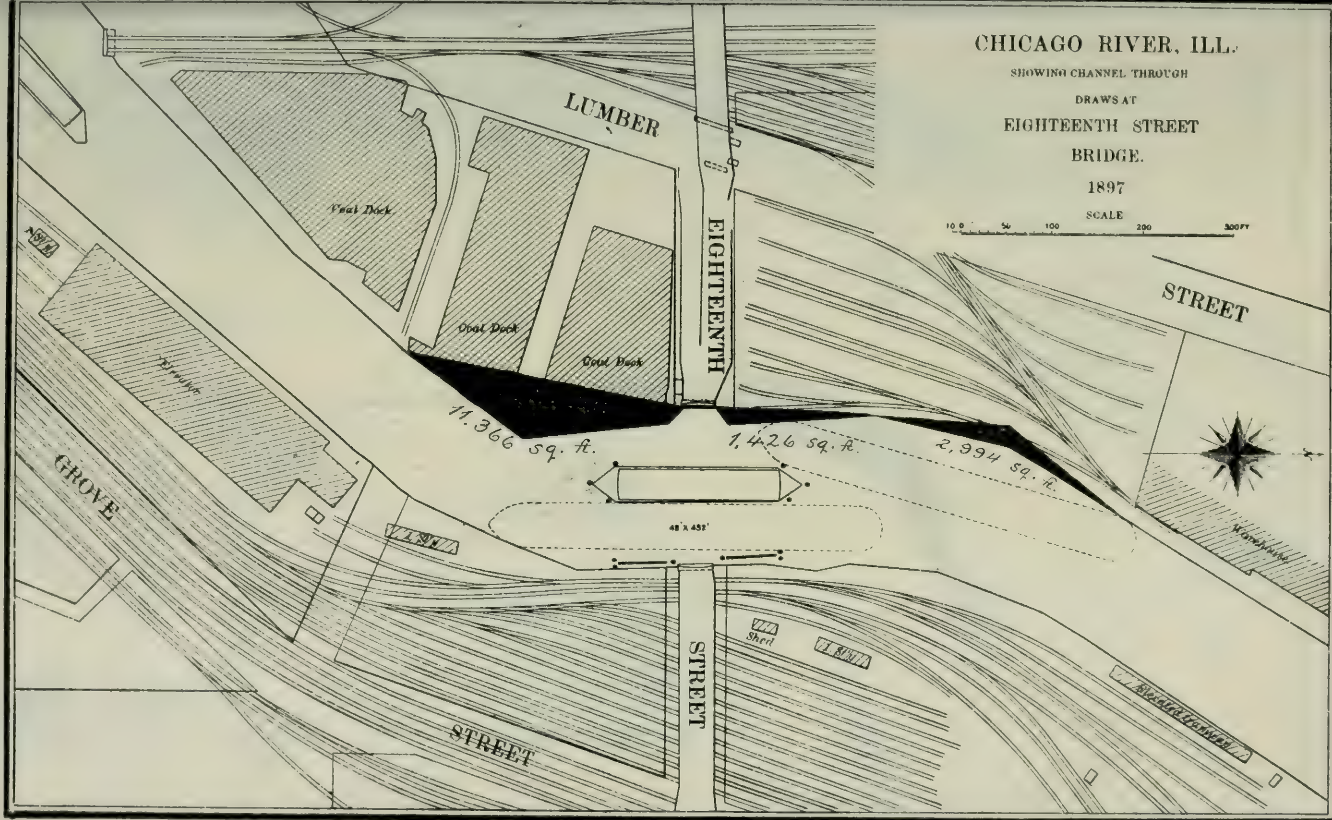
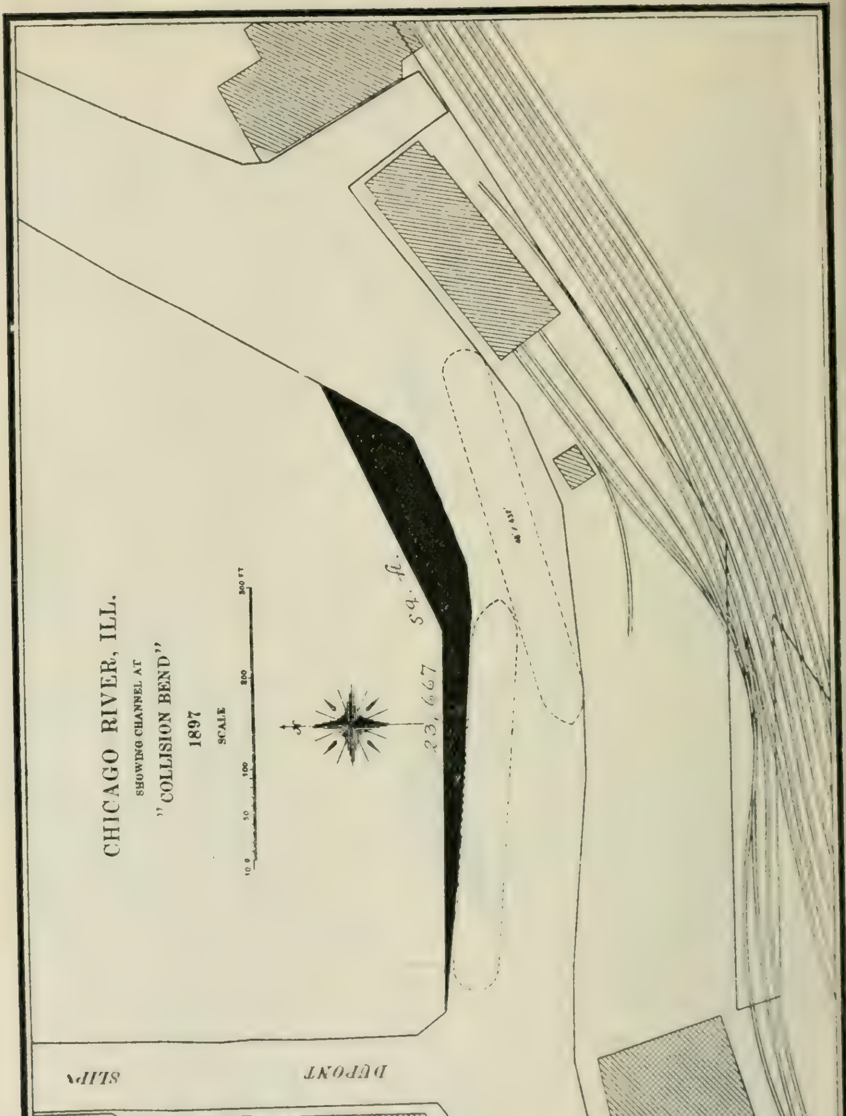


Fig. 401, Sketch B-1.


CHICAGO RIVER, ILL.
SHOWING CHANNEL AT
"COLLISION BEND"
1897
SCALE
23,667 sq. ft.
DUPONT
SLIP
STREET
HALSTED

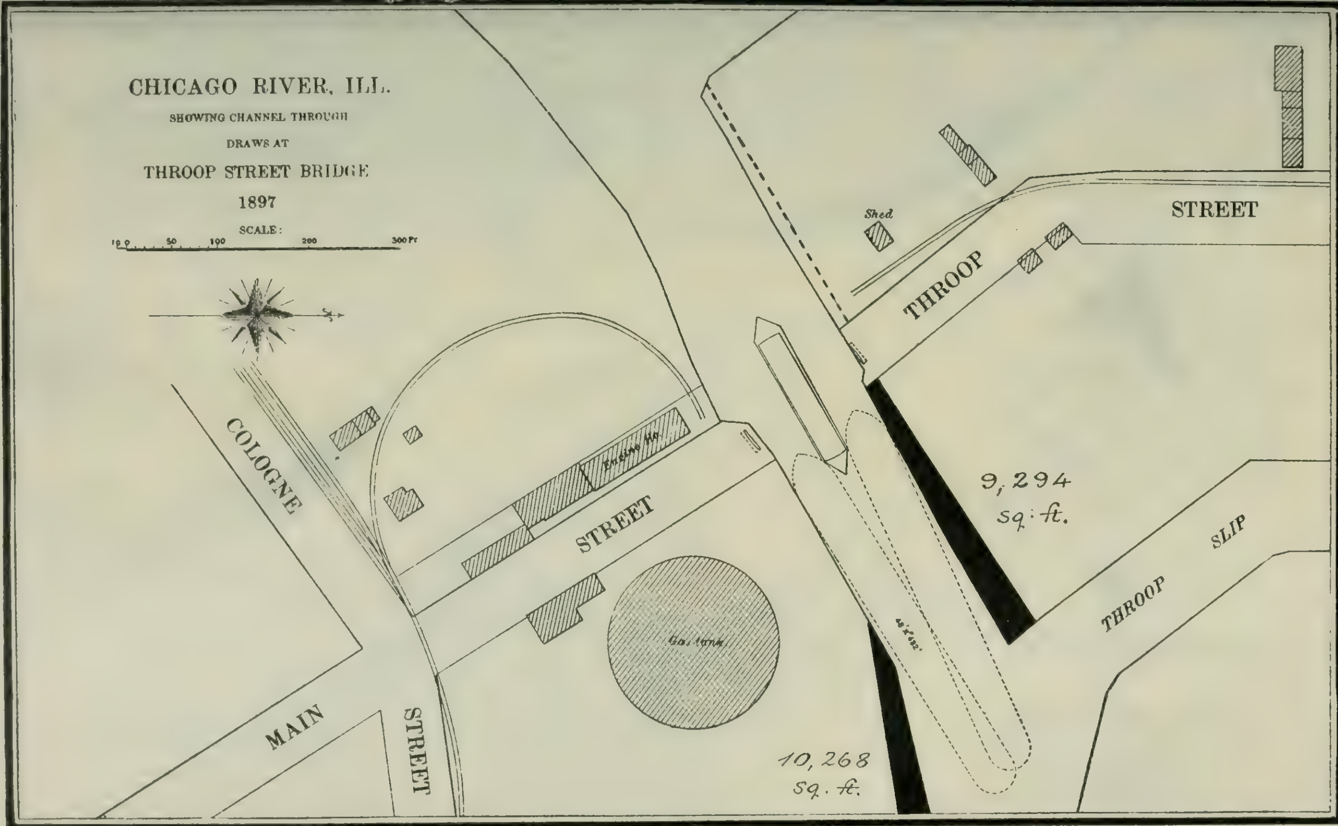


Fig. 403, Sketch B-3.

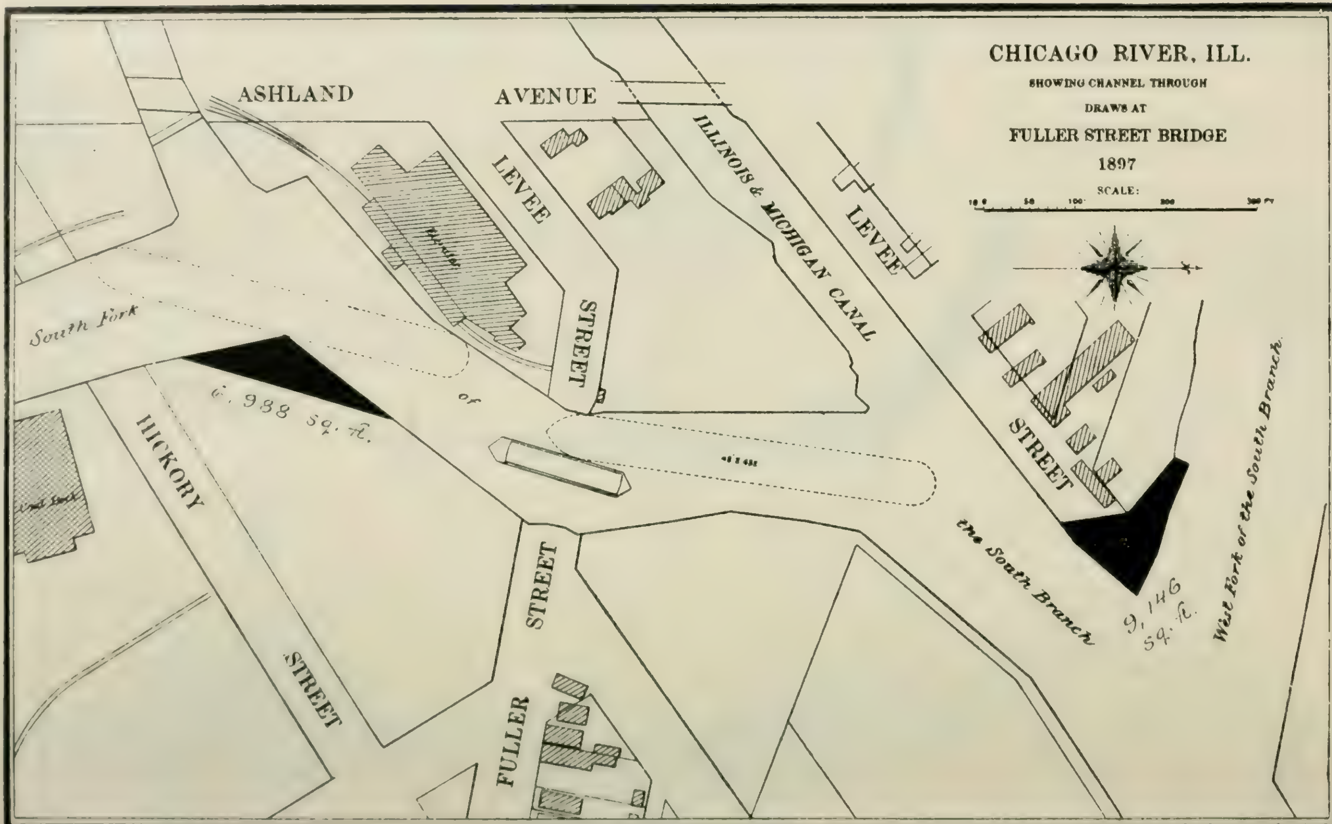


Fig. 404, Sketch B-4.

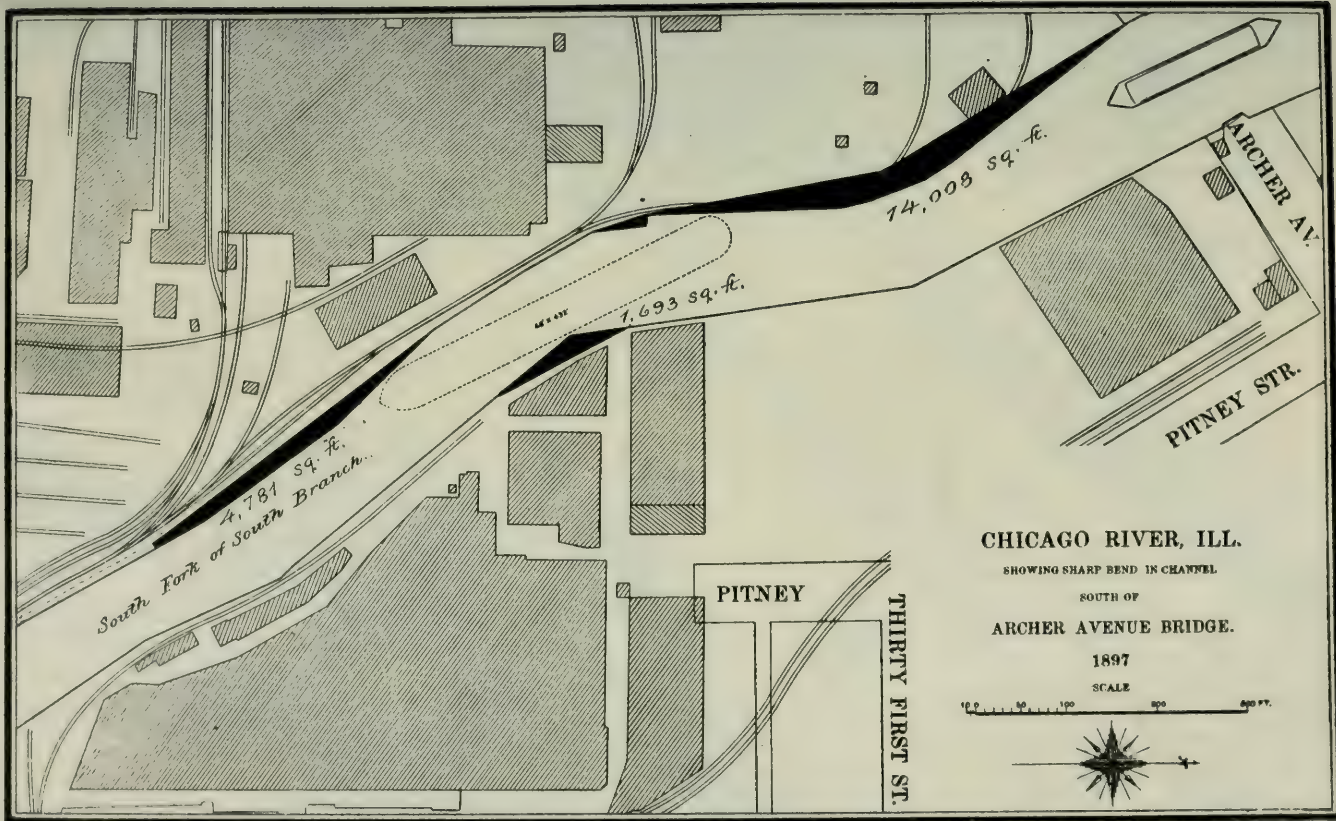


Fig. 405, Sketch B-5.

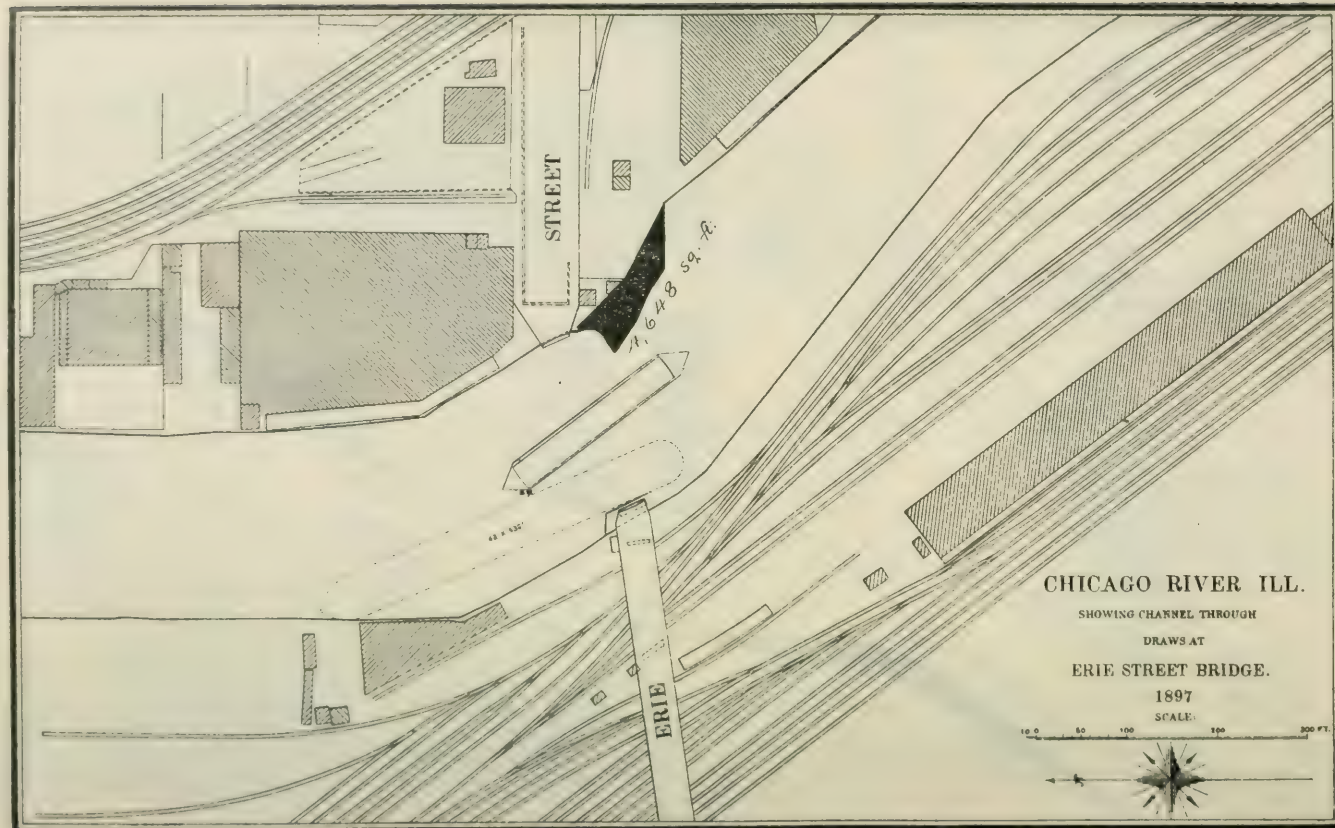


Fig. 406, Sketch B-6.

Fig. 407, Sketch B-7.

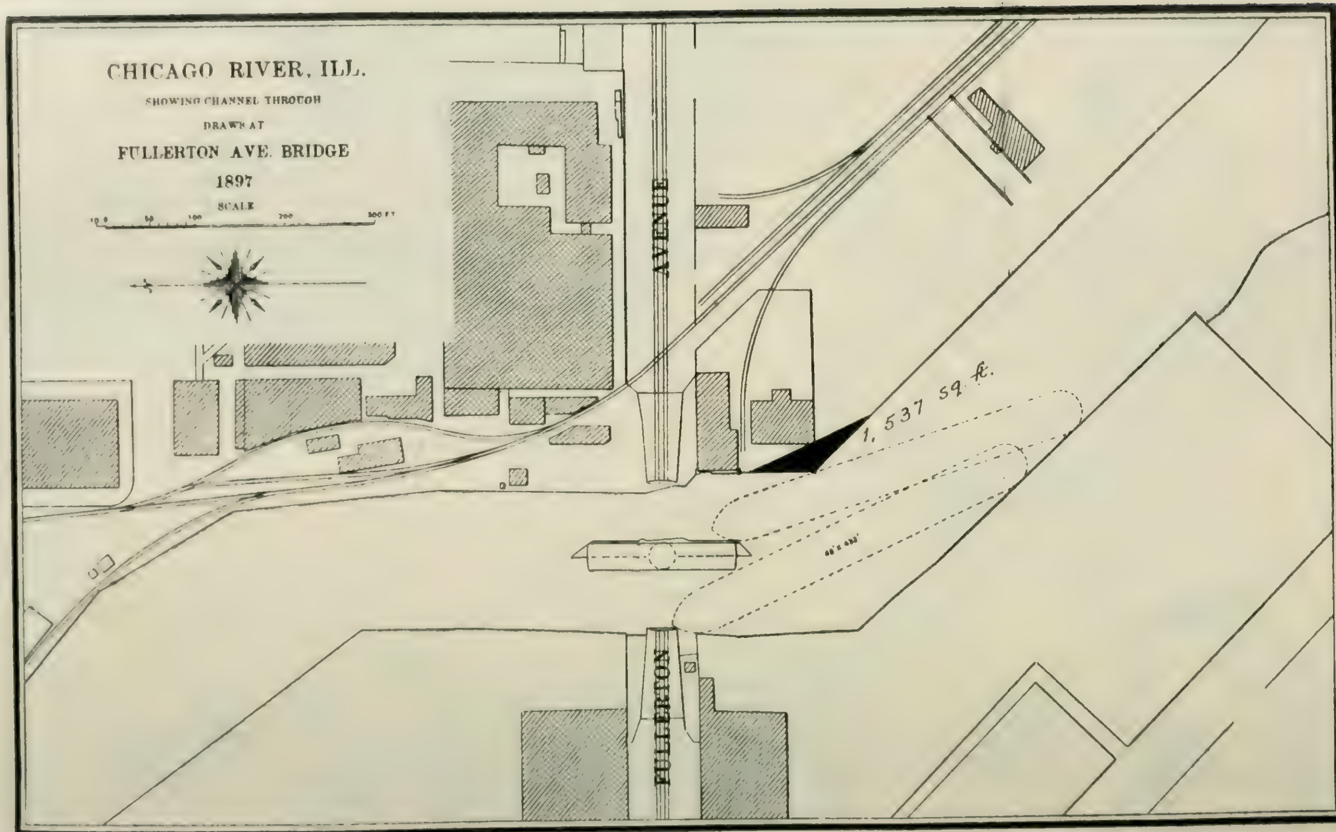


Fig. 408, Sketch B-8.

therefrom. Across the river from the Steel Company's land is a protruding corner, where 1,693 square feet are to be removed, as shown on the same sketch.

On the north branch we find, at Erie street bridge, sketch "B-6," Fig. 406, a triangular piece of ground extending directly in front of the east draw. A part of this has long since been condemned by the city, but never removed, and the impassable draw has for years been used as a resort for old hulks and the like. A piece containing 4,650 square feet will be here taken off. On each side of the river south of Webster Ave. sketch "B-7', Fig. 407, are docks protruding more or less in front of the respective bridge-draws and these will be sliced off. The similar condition on the south side of the river and west of the Chicago & North Western railroad bridge, will be similarly treated, as shown on the same sketch. South and east of Fullerton avenue bridge, sketch "B-8", Fig. 408, is a corner in the dock which would not allow the large boat to make the necessary turn, to enter into the east draw, and enough will be cut off to make this possible. The west draw could not be made passable, owing to the dock on the west side of the river. This is the last point to the north which has been proposed for improvement, under the approved project.

The whole project contemplates the purchase and removal of 123,100 square feet of land and the construction of 4,790 linear feet of dock, in front of the removed land.

All the principal preliminaries for this work have been completed. All that is needed for commencing active operations is the necessary appropriation ; and Congress holds the electric button, a touch upon which will set the wheels of activity in motion.

When the work here outlined has been completed, a very considerable improvement will be found over existing conditions, but the river will still be far from what a river in a city of the size of Chicago should properly be.

If I correctly remember and understand the law governing the sanitary district, it requires that the canal shall not only have a capacity for the discharge of 600,000 cubic feet, and carry a minimum of 300,000 cubic feet of water, per minute, but that for every increase in population of 100,000 there must be an increase of 20,000 cubic feet of water per minute through the canal. How is this periodical increase in the flow of water to be provided for? The discharge through the river must then also be periodically increased. The extent of the lake traffic, necessarily affected by a river current, is also expected to grow in proportion. Can all this be done if the already iusufficient dimensions of the river remain unchanged.

These are questions worthy of serious consideration by those most directly interested, and, if it be shown and admitted that the enlargement of the discharge section of the river *is* a necessity,

would it not then be self-evident that the sooner this is done the cheaper and better would it be for all concerned.

3. CHICAGO RIVER AS IT MIGHT BE.

We read frequently in the newspapers that "Chicago leads," in one thing or another; and so it unquestionably does in many things; but I venture to assert that no good Chicagoan would be willing to lead an unsuspecting stranger down to the brink of the river and exhibit *that* as a leading feature of the city. The river certainly leads also—or will in the near future—to the Drainage Canal; but as a sight of beauty, verily it leads not.

It is the universal custom in European cities that where a waterfront exists it is made the most ornamental part of the city. The reverse is here the case. It cannot be denied that the Chicago river is in reality but a large navigable sewer, with most of its banks as repulsive as they very well could be made.

A speculation on what the river might be must necessarily be vague and unsatisfactory, unless a reasonably clear conception can be arrived at, as to what would ultimately meet with the general approval of the public with regard to harmonizing utility with adornment. If Chicagoans desire the river to be exclusively a means of securing the greatest possible profit, and an outlet for its sewage, without regard to the laws of beauty, then the present river has all the necessary qualifications, except the dimensions. This difficulty could be remedied by the changing of all the center pier bridges to center channel bridges. But should they take the same pride in the general appearance of the river region as they do in other parts of the city, that are beautified by parks, boulevards, handsome buildings and so forth, then the most radical alterations would be found indispensable. Let us assume that the people of Chicago had begun in earnest to realize what a repulsive looking place this river region really is, and to picture in their minds how such a locality would appear, say fifty years hence, surrounded by a then richly and handsomely built up city of a metropolitan aspect. Could such a combination possibly be satisfactory? Would it not give to a cultured mind about the same impression as the sight of a priceless diamond on a soiled shirt front?

Let us now imagine, as vividly as we can, the appearance of this city some fifty years hence, great and beautiful, with perhaps some four or five million inhabitants, full of new and wonderful inventions of all kinds imaginable, everything grand, glorious and modern; everything improved and up to date except the river. Amid all this glory we find winding its way, a crooked narrow, dirty river, bordered by rotting docks and old wooden warehouses, navigated by but a few small old vessels, because nothing but the largest kind of vessels would then have been built for many years back, and these can not enter the river, over the tunnels, through the bridges and by its many bends and

turns. What impression would such a sight create? Would it not give birth to the most earnest wish that the river had advanced with the general progress of improvement so as to form a worthy companion piece to the rest of the beautiful city, in general appearance as well as in size?

Again, let us by aid of imagination take in another and more cheerful view, and assume that the river *had* been improved together with the rest of the city, and instead of the disheartening spectacle described above, find, at least in the so-called down town district, a broad stream,nowhere less than 250 feet in width, lined with stone or concrete docks, comparatively straight, no protruding corners, bridges stretching across the full width of the stream and consisting of three distinct parts, viz: a basculae bridge in the center for the passage of vessels, and a fixed arch of iron or stone on each side under which tugs might pass; the building line 50 or even 100 feet back from the edge of the docks, and such buildings used for wholesale houses, offices, etc.; the channel from 20 to 25 feet in depth, and the docks lined with passenger steamers for the traffic between the lake ports. Further up the river we would find the heavy business for the city's supplies, such as coal and lumber yards, elevators, etc., located as far as possible in slips, so that the principal highway might be kept clear and unobstructed, and in readiness for further extension, in due time, of the more elaborate kind of improvement as circumstances may require. All bulky goods, in transit, handled in the suburbs, say at Calumet harbor, where facilities are favorable for this kind of traffic. Would not such conditions be more to the credit of a great city than that pictured first?

But with every year that rolls by the necessary changes would involve greater expense and increased complications and difficuties until, if delayed too long, it would be almost impossible to solve the problem in a manner at all satisfactory. Such a transformation as hinted at above could not, of course, be accomplished in a few years. It would very likely take forty or fifty years, but what to me appears to be of the greatest importance, if not an absolute necessity, if desirable results are to be attained in the end, is the establishment at the earliest time possible,of a definite and complete plan of improvement, in accordance with which the successive administrations may each in their turn harmoniously exert their best efforts toward the final accomplishment of the plans once adopted.

I have not the least doubt that many, probably a majority, possibly all, will say that such a plan is visionary, too radical, impracticable, too expensive; in fact, out of the question. That may perhaps be so, and again it may not. It has not been my intention to advocate any particular scheme or plan, still less to enter into details, but merely to call attention to what is and what might be, and thereby possibly awaken an interest in this subject that eventually may lead to a change in the so common and apparently

accepted notion, that the river region must inevitably form the dirtiest and ugliest part of the city, whereas, judging by what has been done elsewhere, it could be made one of the most attractive parts.

But, someone asks, will it not be very expensive? Of course it will. All great improvements are expensive. So are the park and boulevard systems; so will the Lake Front park be; so are the Art Institute, the Public Library and numerous other public institutions, not used for the accumulation of wealth, but to adorn the city and contribute to the promotion of the culture and refinement of a city in which we all take a pride.

There are in this city a sufficiently large number of public spirited men who, if the interest was once aroused and the subject was deemed worthy, could accomplish wonderful results in the improvement of the river region with no more difficulty than was found in creating the beautiful, ever memorable White City, out of the swamps of Jackson Park; and that was an enterprise designed for temporary use only. The improvement of the river region would be for all time to come.

To indicate how water-fronts might, and do in many countries, form ornamental parts of cities, a number of views were secured and shown by means of the stereopticon, at the reading of the paper.

Three of these views accompany the paper, viz: The beautiful Thames Embankment, Fig. 409, the popular London Bridge, Fig. 410, and the Harbor in Stockholm, Sweden, Fig. 411, with the National Museum to the right. The very extensive waterfront in this city is everywhere lined with fine-cut granite quaies and the effect of its, by nature so greatly favored, location is thus further improved by artificial adornment.

DISCUSSION.

President Noble: Mr. Liljencrantz's paper is a very interesting and valuable record of the state of things along the Chicago River, and we hope to have a full discussion of the subject.

Mr. Condron: Will Mr. Liljencrantz kindly point out to us on the index map the locations of the improvements that have already been begun—that is, the land that has been condemned—to give us some idea how far up the river crafts of reasonable size, not necessarily the largest sized vessels, but the larger vessels, are able to go at the present time.

Mr. Liljencrantz: The largest vessels cannot go any farther than to the beginning of each of the branches, provided that, as I have stated, they have been able to pass over the LaSalle street tunnel. As for the improvement, so far only the dredging has been done, viz., from the harbor to the stock yards in the south fork of the South Branch, and that has been redredged up to the foot of Twelfth street, and the contractors are now at work re-

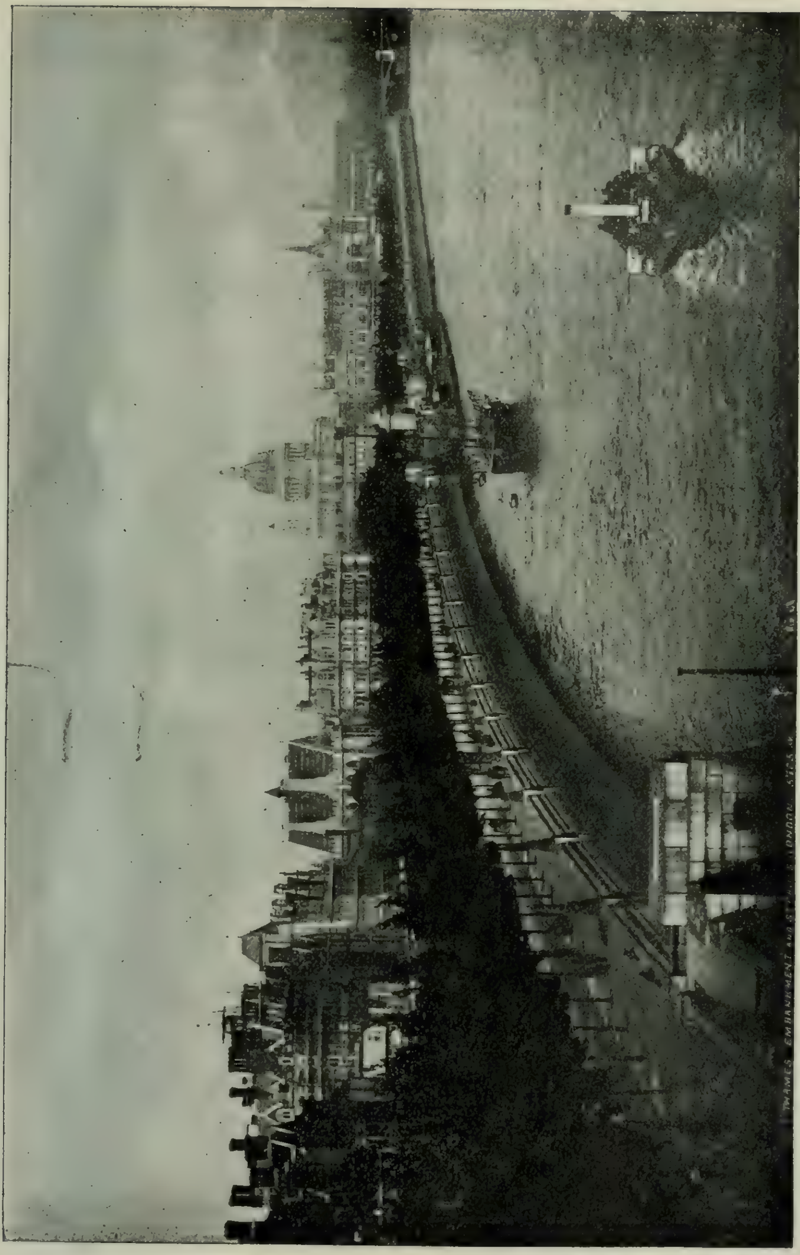


FIG. 409. THAMES EMBANKMENT.

FIG. 410. LONDON BRIDGE.

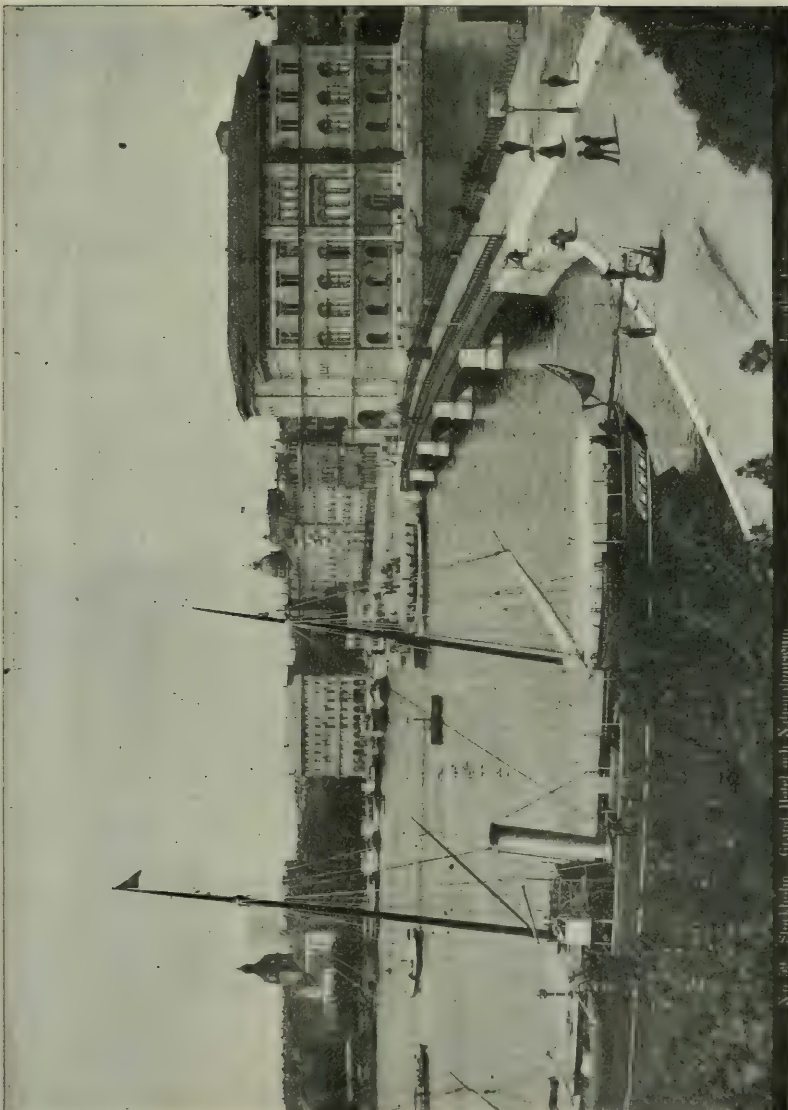


FIG 411. HARBOR IN STOCKHOLM, SWEDEN.

dredging the balance down to the harbor. In the North Branch the work commenced at the forks and that work has been completed nearly up to Fullerton avenue. The dredging will be extended to Belmont avenue, which is considered the head of navigation. At present I do not believe that a boat can go beyond Fullerton avenue that would draw over say six or eight feet, but when the dredging is completed, a boat drawing sixteen feet may reach the said head of navigation.

Coming down the South Branch the first place where a removal of land is proposed is at Eighteenth street. One part will be cut off north of the bridge and a larger tract south thereof. The index map shown herewith is merely intended to indicate the streets and their relative positions.

Mr. Condron: What is now the largest vessel that can reach Eighteenth street?

Mr. Liljencrantz: The accompanying table II. will give information of this kind.

Mr. Condron: How far can a vessel of that size go on the North Branch at the present time?

Mr. Liljencrantz: The table just mentioned will give information as to the North Branch also. The Northwestern Railroad bridge has lately been improved, but the Chicago, Milwaukee & St. Paul Railroad bridge is quite a bad obstruction. The bridge crosses the river at a very acute angle and makes it difficult for a vessel to pass. The draw on the west side is the only one available for vessels; the east draw is so narrow that nothing but a tug can pass through and it has never been dredged until April of this year. This was done to enable tugs to pass, without loss of time, when the west draw is used by vessels. At Erie street bridge a parcel of land will have to be removed which lies directly in front of the east draw, which has never been used on that account, but is full of old scows, sunken tugs, etc.

Mr. Condron: I have seen on the North Branch, as far as the works of the Illinois Steel Company, vessels that I should judge were 300 feet in length loaded with ore.

Mr. Liljencrantz: A 300 foot long vessel may reach that place, but cannot go beyond the C. M. & St. Paul Ry.'s bridge. To make this possible, it would be necessary to change the location of said bridge as well as the adjacent channel, requiring the condemnation of a great deal of land. Few of the landowners seem willing to assist in securing an improved channel unless they get a good price for their land.

President Noble: What depths are to be obtained under this re-dredging?

Mr. Liljencrantz: Seventeen feet.

President Noble: How much filling have you had come in, during the interval between original dredging and re-dredging?

Mr. Liljencrantz: In several places there have been as much as two to three feet, mostly along the sides of the channel. The

TABLE II.—*Showing how far vessels of dimensions given can navigate Chicago River and its Branches.*

Dimens'ns of vessels.	LIMITS WHICH CAN BE REACHED BY VESSELS. In South Branch.	In North Branch.	In North Branch Canal.
48'x432'	"Might possibly" squeeze through Randolph and Madison streets bridges if it can pass over LaSalle street tunnel. Then to Taylor street bridge.	Only to the first, the Chicago & Northwestern Ry. bridge.	Cannot reach the canal.
42'x340'	To Eighteenth street bridge.	To Division street bridge.	To Halsted street bridge.
42'x325'	To Eighteenth street bridge.	To Division street bridge.	To Halsted street bridge.
42'x305'	"Might possibly" squeeze through Eighteenth street and Fuller street. If so, can go to Indiana state line railway bridge, west arm of South Fork of South Branch.	To Division street bridge.	To Halsted street bridge.
40'x305'	To Indiana state line railway bridge in west arm of South Fork of South Branch.	To Chicago, Milwaukee & St Paul Railway bridge (north of North avenue).	To Chicago, Milwaukee & St. Paul Railway bridge.
38'x300'	To Indiana state line railway bridge in west arm of South Fork of South Branch.	To Chicago, Milwaukee & St. Paul Railway bridge (north of North avenue).	"Might possibly" squeeze through Chicago, Milwaukee & St. Paul Railway bridge and go to the main channel in the North Branch.

Table taken from the report of the chief of engineers for 1897.

dredging is done to within fifteen feet of existing docks, and the undredged part gradually slides into the channel, especially when affected by the wheels of passing steamers. Similar is the case at each of the protection piers of the bridges, said piers being open and containing a great deal of soft material. The many sewers emptying into the river also contribute to the shoaling.

Mr. Reichmann: What boat was that described as 432 feet long, with forty-eight feet beam?

Mr. Liljencrantz: That is one of the Rockefeller Company's boats; I think they have two or three.

Mr. Reichmann: Has that been in the Chicago ports?

Mr. Liljencrantz: I do not think they have ever tried to bring any of these in.

Mr Reichmann: You show a semi-circular end of this boat. Do you know where a person could get the exact dimensions of that boat?

Mr. Liljencrantz: You can find in the "Annual List of Merchant Vessels of the United States," on file in the U. S. Engineer's office, an account of all the sailing and steam vessels of the United States, their dimensions, draft and tonnage, &c.

Mr. Reichmann: I notice Major Marshall reports the largest vessel coming into the Chicago harbor is the Christopher Columbus, and I notice that in the advertisement they only claim that boat to be 260 feet long. I looked at Major Marshall's report and that states it is 380 feet long.

Mr. Liljencrantz: In the list referred to, the dimensions of Christopher Columbus are given as 362x42′, which refers to the dimensions on the *water line*.

Mr. Condron: Steamers of the Great Northern line have not been able to come into Chicago, I believe.

Mr. Liljencrantz: The object of the improvement should not be to provide for the boats that now come in, but to provide for the boats that might come in twenty or thirty or forty years' time. The most expensive kind of improvements to make are the improvements necessary for a year or two, instead of making them so as to be ample for a great many years to come.

Mr. Potter: In speaking of dredging, how often would the river or the branches have to be redredged to allow a constant channel of sixteen feet?

Mr. Liljencrantz: Well, this is hard to answer definitely. Probably every year, especially as long as the sewers empty into the channel.

Mr. Potter: What is the time between two dredgings, about?

Mr. Liljencrantz: The dredging commenced in November, 1896. The south terminus at the stock yards was reached in September, 1897. The work of re-dredging was done back again toward the harbor, and has been completed as far as to Twelfth street. As soon as a section of from 1,000 to 1,500 feet is found to be of suf-

ficient depth, it is formally accepted. If this was not done there would be no end to the work.

Mr. Potter: Do you take soundings at any regular periods?

Mr. Liljencrantz: No. Only before the work is begun, to show where it is required, and after a section has been reported as completed. There is an inspector for each contract, and he takes frequent soundings, both from the dredge and from a boat to make sure of a uniform depth.

A Member: Will you tell me the draft of the boat that is 400 feet long?

Mr. Liljencrantz: When it is loaded to its full capacity?

A Member: Yes.

Mr. Liljencrantz: I could not say, but probably from eighteen to nineteen feet, but it could not go up the river if loaded to its full capacity.

A Member: I understand from a steamboat man that the boats only receive a partial load on the river and then load up at the mouth of the river.

Mr. Liljencrantz: That is probably often the case, as the LaSalle street tunnel restricts the carrying capacity.

Mr. Gerber: What would be the probable cost of making the Chicago river 150 feet wide?

Mr. Liljencrantz: That is a problem which has not yet been solved, and it would involve complicated details. Much depends upon the interest and liberality of the property owners.

Mr. Appleton: I notice in the diagram shown, the vessel 48 by 432 will be enabled to pass a good many points if the corners are taken off, indicated in the Figs.; but I notice in some cases there is no width for two such vessels to pass. At the place called "Collision Bend"; there is apparently an attempt made to widen the river for two vessels to pass.

From this map it is apparent that there is an attempt to make room for two large vessels, while in most other cases there is no room for two vessels. I was going to ask Mr. Liljencrantz how far it was intended to make room for two boats of that size, or if that was contemplated at all.

Mr. Liljencrantz: On account of the sharp bend in the river at this place, the vesselmen have frequently experienced a great deal of trouble in passing, particularly if a boat is unloading at one of the docks. A large tract will therefore be removed here. The improvement will enable two large vessels to pass one another. The same result has been aimed at in other places, where practicable, considering available funds, etc.

Mr. Appleton: As I understand it, then, when these black corners shown in the illustrations are removed there will be room enough for a boat of that size to go up the river, but not room all the way up for such vessels to lie alongside the dock and discharge. If the river is to be made available for loading and unloading all along the whole length

of it, it would have to be widened a great deal more than anything that is indicated now. Of course in any improvement we have to start with a vessel of some definite size, and that probably being the largest one on the lakes, was chosen in this case. Now, if the whole of the Chicago river is to be made sufficient width and depth for that class of vessel, it will require a great expenditure of money, and what this city needs, I should judge, would be an improvement to keep it abreast with other cities, and I would like to ask Mr. Liljencrantz if all the principal cities on the lakes are able to accommodate vessels of that size?

Mr. Liljencrantz: Only a few of them are. As stated in the paper, this improvement does not pretend to make the river what it properly should be. There is a certain sum fixed for this work, and the proposed improvement can therefore provide only for the removal of the most obstructive places, to keep within that sum. If the cost could be disregarded, then the improvement should aim at a width of channel which would allow two large vessels to pass at meeting anywhere, even though others were unloading at the docks at the time.

Mr. Appleton: Mr. Chairman, I would ask, how many places can that sized boat get into now; how many harbors would accommodate that boat?

Mr. Liljencrantz: Such boats could be accommodated in Ashtabula, Buffalo, Calumet, Cleveland, Detroit, Escanaba and Marquette harbors, and possibly a few others.

President Noble: The larger boats that have been engaged in the business of carrying iron ore, loading in Duluth harbor, or some point in the vicinity, have been loaded to 17 or 18 feet draft, and they discharge that either at Lorain, Ashtabula or Cleveland, I think. There are one or more ports at each end of the route where vessels of that class are now loaded and navigated at full draft. It was the intention to provide a channel for twenty feet of navigation from the head of Lake Superior to the foot of Lake Erie, and a channel of that depth has been excavated, but during the progress of the improvement the character of the river has been somewhat changed, and the depth expected has not been realized. The depth is now one or two feet short in some places of what was expected, on account of the water draining off more readily through the enlarged channel.

Mr. Liljencrantz: I might mention that I was told a few days ago, that there is now a vessel on the stocks that is to be 500 feet in length and 50 feet beam, but I cannot say whether the boat has been named as yet.

Mr. Condron: Is not that vessel to be built by F. H. Wheeler, at Bay City? I believe they are building such a vessel for the ore trade.

Mr. Liljencrantz: Yes, it is being built at Bay City.

Mr. Strobel: I am not prepared to discuss what should be done with the Chicago river. There are a great many considera

tions which belong to this subject, and private interests are very much involved. I notice that in the attractive lantern views of European rivers and harbors, movable bridges are conspicuous by their absence, and I believe that the problem of enlarging a small river such as this, and virtually making it a deep-sea harbor through the heart of a big city, is a very unusual one that has never been undertaken abroad. The rule has been to take only the light traffic on a river through the city, confining the heavy traffic to the outer confines of it. Thus on the River Thames in London the large ships pass through but one bridge, viz., the "Tower" bridge, and only very few do that. This bridge, as is well known, is of very recent construction, and it is probable that, after a time, no large ships will pass even this one structure. There are no movable bridges over the Thames above the Tower bridge, and only the lighter craft pass further up the river.

The author has called attention to the importance of adopting some comprehensive plan of improvement for the Chicago river. This city at the present time has no means, and it would seem as if the money required for any radical improvement of the river should be raised in some other way than by appropriations payable out of the taxes. Future generations should pay their share, but bonds cannot be issued under the laws now in force. It may be possible to do something when the new revenue law passed by the last legislature becomes operative.

I think the paper is a valuable one in that it shows how reckless and heedless we have been in connection with the Chicago river, and how necessary it is that future improvements be planned in the careful and comprehensive manner which the great importance of the subject demands.

Mr. Liljencrantz: In regard to the stereopticon views I wish to explain that they were intended merely to show what a water front "might be made to look like." They are not what I had wished to show, for we had to take what could be had, not what was really wanted.

How an improvement should or could be paid for is a matter of detail beyond the scope of this paper. I only assert the importance of looking into the subject *now*, and that some feasible plan be decided upon, according to which future improvements might be carried out to make the river region keep up with the rest of the city with regard to appearance as well as utility, for the time must necessarily come sooner or later when the citizens of Chicago will wish most earnestly that provisions for that purpose had been made *while yet there was time.*

All details should be decided upon only after careful and mature consideration by competent and interested citizens of Chicago.

Mr. Tratman: I think a case in point very similar to Chicago is the city of Glasgow. It is situated on the river Clyde, which was originally a very small stream, quite unnavigable. By municipal enterprise, however, the stream was widened and deepened,

and fine docks were built, with the result that the city has become one of the largest ports in Europe, both for ship-building and commerce. I was rather in hopes that Mr. Liljencrantz's lantern slides would show some views in that city. Concrete is now being substituted for stone masonry in many cases, and concrete walls along the Chicago river would be far cheaper and much more quickly built than the stone masonry generally used abroad. It seems to me that the most important part of this paper is what it suggests, rather than what it tells of work done. This work shown in black on the plans is all very well, considering that this is all we can do under present conditions, but with a river having the traffic of the Chicago river, we ought not to be content to do a little hacking and scraping here and there. The outlines of the boats on the plans show that the center piers of the drawbridges are among the most serious obstructions. If we could remove all those piers and get those corners cut off, we should have quite considerable improvements for the boats and the traffic of the day, but, as Mr. Liljencrantz says, fifty years hence it will be a very different matter. It seems to me that some steps ought to be taken by the city now to adopt some general plan and some general scheme for the whole work, and then carry the plan out gradually as it can raise the funds. It is not safe to say that because the largest boats now in service are used in certain specific traffic, we need not provide for larger boats than those now used in regular traffic. As Mr. Liljencrantz says, the lake steamers are getting larger all the time. The largest boat I know of is about 475 feet long; now I hear tonight of one 500 feet long being actually on the stocks. This is going to be as large as an ocean boat. Of course the expense of improving the river as it ought to be improved will be something enormous, but that has not been an obstacle in other great public improvements, and I do not see why it should be in this, if the work is carried on bit by bit. The great outside influence of such an improvement, in increasing the general importance of the city, must also be taken into account. If the work is to be carried out, it will be cheaper to do it on a regular systematic plan than to hack and scrape here and there, and possibly fill in corners and put up buildings that have to be taken away again later for some other little bit of improvement work. I think the city ought to adopt a general scheme, and to strictly enforce any regulations as to dock lines or limits affecting the future improvements under such a scheme.

Mr. Condron: Regarding what Mr. Tratman said—Mr. Liljencrantz states in his paper that "In June, 1869, there was established by an ordinance passed on the 11th of that month, certain dock lines along a portion of the South Branch," and further goes on to state that this ordinance has been more observed in the breach than otherwise. As I understand it the ordinance is on paper, and that is all, and in fact a very large ma-

jority of the docks have been built without any restriction by the city. If the ordinance of 1869 was in the right direction, it should be followed up by other and similar laws which should be rigidly enforced. The river would probably be better today than it is if all the laws made respecting it had been enforced.

CORRESPONDENCE.

SAMUEL M. ROWE, MEM. W. S. E.

To one who has watched the development of the city of Chicago and its harbor and commerce for over fifty years, the delineation given in Mr. Linjencrantz's paper marks a summing up that at this time is exceedingly valuable, showing as it does that the point is reached for prompt and intelligent action.

It does not seem, however, that the conclusions reached cover the grounds commensurate with the lesson taught by the past, but rather serve as a step toward a demonstration that a halt should be called and a radically different policy should be inaugurated.

It is true that the removal of the center pier in all the bridges and the lowering of the crown of the tunnels would improve the present conditions, and in a measure remove most of the obstructions now encountered.

In view of the past we believe much more is called for. It is evident that in any effort to provide for Chicago's commerce large expenditures are involved, in view of which care should be taken to provide for the future on a scale which will not end in the same embarrassments in the near future.

The past and present policy certainly tends to a condition that will eventually force the abandonment of the Chicago river as a harbor, and the substitution of a more distant harbor for the lake commerce, a result far more costly and disastrous to Chicago values and to Chicago's business than can be measured by the cost of any elaborate system of deep water harborage that can be planned.

The Calumet district is fraught with great possibilities.

The facility with which ample deep water can and is being secured is already diverting much of the heavier shipping, both as to tonnage of vessels and volume of business, can be taken as a pointer to the ultimate outcome.

On the lake front there is still deep water space that is available, notwithstanding the lake front park, that can be improved in a manner which will effectually meet the increasing necessities and leave the river free for such degree of usefulness as it now has or is capable of being made to meet in the future.

Of course, the connections necessary to make the outer harbor available will necessarily be elaborate and costly, but they are by no means impracticable.

You may estimate the cost of outer harbor and its necessary

connections and include the cost of the Chicago river to its utmost, and still the sum of these will not approach the sum of the loss to the city of its shipping trade that would result from its diversion to the Calumet and Indiana points.

Just as necessary is it to Chicago that no mistakes be made in this as in the "Sanitary" matter, and it is to be hoped that some L. E. Cooley shall be raised up to formulate some equally grand plan to meet this case.

DWIGHT C. MORGAN, MEM. W. S. E.

The paper of Mr. Liljencrantz, member of our society, on "Obstructive Bridges and Docks of the Chicago River," just received, is exceedingly interesting and instructive.

To the observing of our profession in Chicago and vicinity the conditions existing in and along the Chicago river have in a greater or less degree been apparent; but it has remained for Mr. Liljencrantz to present in concise form the situation as it is, as it will be and as it might be.

His treatment of the subject is broad and the omission of technical details at this time renders the paper of great value, because it is capable of being readily understood by the general public, whom I believe should be more fully apprised of the conditions.

In the discussion that is to take place there will doubtless arise differences of opinion on the subject. If the views entertained by a majority of the committee appointed by the society in 1891, and reporting in May, 1892, upon "The Railway Problem of Chicago in Relation to Terminals, Rapid Transit, Marine Commerce and Related Interests," are to be accepted as the solution, then according to the report, the present harbor entrance through the business center of Chicago should be closed. The report of the committee, though not endorsed by all its members, is exhaustive and covers probably the most tangible engineering propositions, but it is a noticeable fact that but little space is devoted to a plan of improving the present harbor entrance. It is specifically stated, however, that "it cannot be maintained as at present without jeopardizing, if not seriously injuring, the city's future interests." Upon this point doubtless all informed persons will agree.

It is upon the remedy to be applied in overcoming the difficulties that differences of opinion arise.

The paper of Mr. Liljencrantz adds more valuable matter to the subject, and it appears to me that, with the complete data now at the command of the society, a strong effort should be made owards the attainment of the desired result, viz., that the marine facilities of one of the principal cities of the world may be made capable for its present needs and future requirements.

The progressive spirit of Chicago should be inspired. To do this her citizens must become interested. They must show how greatly the results of a well-defined plan of improvement will

benefit the commercial interests of the city. They must be shown the desirability of improving the river—that one stultifying sight to which they, as well as the traveling world, are compelled to bear witness.

The preparation of papers upon the subject and their discussion by members of the society are essential and important in many respects, but if the findings are meant only for the enlightenment of the members of the society (to be sure they are interesting), it will be found that the labor expended will be absolutely unproductive of results. It therefore remains for the society to exercise one of its functions and devise a means of interesting the business men, public men and citizens of Chicago in the merits of the proposition.

The facts are undisputed. It is therefore not necessary to present the details of any plan of improvement. Details are after-considerations in this instance, but the agitation of the present conditions and the imperative demands of the present and future, should be so set forth as to arrest public attention and lead to such action as would carry with it authority and energy. Such a movement could produce results.

I would suggest, therefore, that a committee of five members of the society be appointed to consider and report not later than the first meeting in August, 1898, upon a plan of action wherein the society would be most likely to produce greater public interest in the matter, especially among the business and public men of Chicago.

I believe if we can be instrumental in starting the public interest that the enterprise of Chicago's citizens would never let go of t until the desired results are assured.

Chicago never abandoned anything it attempted, and it attempted and carried out with wonderful success one of the greatest achievements in the history of the world. I therefore have no serious apprehensions that should she undertake to improve the Chicago river that she would fail in either plan or execution.

Do not understand me to think that much has not already been done in the matter by the society, by the newspapers and by individuals, because I know full well the time and labor that has been expended in the consideration of the subject, and the preparation of the numerous data now available. I therefore make these suggestions in all due respect to those who have given the subject generous consideration, and trust that, if not thought to be a desirable plan, some better line of action may be devised that will lead to the accomplishment of the result desired.

XXXVIII

MEASURING APPARATUS, KING'S COUNTY SURVEY, N. Y.

By Samuel McElroy, Mem. W. S. E.

Read June 1, 1898.

It became necessary under this survey, in 1870-73, to extend over the five towns of King's County, adjacent to the city of Brooklyn, a street system conveniently adapted to that of the city. Four of these towns, New Utrecht, Flatbush, Gravesend and Flatlands, at detached points had some street and block division, but adapted to farm lines in each locality, as a rule. The fifth town New Lots, had a more complete system, which in the main was retained for its area of about 5.47 square miles.

The four towns covering 36.3 square miles, all joined the city line along an elevated ridge which extended southward through New Utrecht to Fort Hamilton on the narrows of New York Bay. The westerly line rested on the Bay, and the southerly line on the ocean or Jamaica Bay.

From the foot of the ridge to the water front on the south, there was a sloping plateau with a fall of about seventy-five feet in about five miles. A population of about 14,000 occupied the four towns.

After a preliminary map of the district had been made and the blocks and street system substantially decided, it became necessary to set monuments which should designate the street and avenue lines, as finally laid down on the maps filed by the town survey commission.

Running accurate lines and angles, and measuring distances accurately, are not at all easy in actual practice, in seasons of continually varying dryness and moisture, heat and cold, sunshine and cloud, and over a country full of obstructions to long sights, under careful cultivation in great part, and in various parts well covered with buildings and ornamental grounds, common to the suburbs of a great city. Over this area it was necessary to establish the future streets of a colossal city, in such a manner, that no future question should arise as to the intention of the plans adopted, or as to the integrity, in detail, of the location to the plans; an integrity, which centuries hereafter, perhaps, are continually to test and criticise. Not only was the problem inherently difficult, but the sense of the commission, in which the superintendent fully sympathized, was that it should be accomplished at the least possible cost, in the least possible time, and in the simplest manner.

The first detail to determine was, what should be taken as a

standard foot. If a city surveyor is to lay out a lot in Brooklyn, his first care is to ascertain what kind of a chain to use, since there are at least three different standards used, in as many different localities. This point is, however, settled by law, and the common English and French measure, adopted by the United States and New York, was formally adopted by the commission, and a local standard yard obtained, duly certified, and is now put on record in the County Clerk's Office. In practice finding on a test of 200 feet, that the standard Brooklyn Commission of 1836, was very slightly in excess, and more convenient for transfer, it was adopted and transferred for our field work use, on two test bases of 500 feet each.

This point settled, the problem of accurate measurement by this standard was next in order; and of this duty one or two things may be said, to illustrate its difficulty.

The Ordnance Survey of Great Britain, and the Coast Survey of the United States, are works of such magnitude as to have been special objects of national care; and of these, the latter, is a very important and very expensive department, under continual annual appropriations and organization. Yet the trained men at the head of departments of this kind, recognize at once one principle, which is, in its nature, of an absolute character, the physical impossibility of making such a survey by the common method of surface measurement, in point of time, cost, and accuracy. For the whole basis of work in this department, from Long Island to the central part of the state of Maryland, but two base lines were measured on the ground, one on Fire Island, the other on Kent Island, the work between these being performed by triangulation, to determine the connecting distances by calculation; and the error, by this process, was found to be not more than four inches on this whole distance.

In making the survey of the Hudson River Valley, for this state in 1866, from Troy to Fort Edward, a very cursory examination of the river banks satisfied me that ordinary measurements were nearly impossible, certainly, so, in view of the limited time and appropriation and the work was therefore done by triangulation, from a base near Troy, with four short base lines, measured as checks, as the survey progressed. In that case I was entirely satisfied to find in a distance of about forty-two miles an error of fifteen inches, and to accomplish the work within the given time and appropriation.

In other words, engineers of experience know the inherent difficulty of making correct measurements, and this difficulty increases as the distances multiply, and we therefore avoid multiplied measurements, wherever it can be done.

In this case, however, the distances for each block, and system of blocks, had to be actually determined on the ground, over this entire area of $36\frac{3}{10}$ square miles, involving a proximate length of street lines of nearly 2,000 miles; and it had to be done

rapidly, with assistants under restricted pay, and in the simplest manner possible, with the ordinary field instruments, the commission not feeling authorized to provide those of a higher class, or of any class.

In coast survey work, the measurement of a base line is made a very serious undertaking, much time being occupied in selecting its site and grading the line of 4 to 6 or 7 miles, for the subsequent measurement; a party of six or seven assistants is used, and the actual time of measurement varies, in the case of six bases reported, from 8 to 17 days each. The apparatus used is delicate, and requires great care in transporting and handling. In point of accuracy, the results are admirable for work of this kind; in one case a coast survey check on a base measured for the Massachusetts survey, near Portsmouth, R. I., over 6 miles long, showing 0.22 feet difference; but this nicety of apparatus and manipulation was inadmissible for us.

In the Brooklyn survey of the outer wards, its accomplished chief, John S. Stoddard, Esq., used a heavy steel chain 50 feet long, of ten bars, which, in measuring, was used with the bars on different inclinations, not being lined on trestles, involving levels and their corrections for each bar and those also for temperature, with transfer points at each length.

John Randall, Jr., an engineer celebrated for his care in work of that kind, laid out upper New York, between 1808 and 1820, using a steel bar or rod 50 feet long, making corrections for inclinations and temperature, using for the purpose a sector of 5 feet radius.

In preparing for the more extensive and varied work of this part of King's county, I felt the necessity of simplifying this important detail. The attempt, in the varying changes of the day, to determine the temperature of a metal bar, laid on the ground, with a thermometer disconnected from it, as to accuracy of register for the bar, and multiplicity of notes and calculations, I wished to avoid; I also wished to obviate the multiplicity of level sights and corrections, and take their chances of error; and, also, the multiplied transfer stakes, for 50 feet lengths. Knowing that soft, clear, seasoned pine was much less affected by changes of temperature than any metal, easy to construct, transport, and handle, I concluded to make a trial of it for our bases.

On this theory I arranged an apparatus, Fig. 412, consisting of a tripod about 7 feet long, carrying on a convenient drum about 600 feet of No. 13 annealed steel wire, and fitted with stay chains and a stout iron pin, to be driven in the ground and keep the tripod in place, when in use; also, a back stay rod, of the same length, driven in the ground, on line, supported by side stay chains and pins; between these the wire was stretched and supported at intervals of about 75 feet, by ordinary wooden flags, fitted with sliding rests and keys, so that when the wire was secured behind the back stay, to a pin firmly driven in the ground, it could

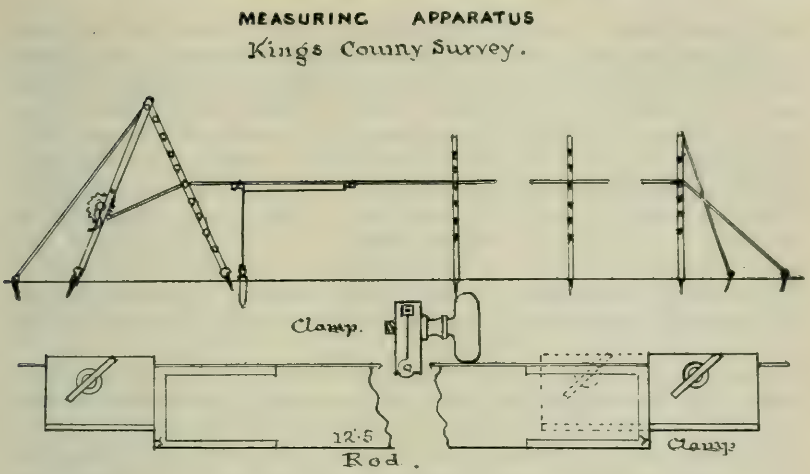


FIG. 412.

readily be brought to a level; or if the ground did not so permit, to a uniform inclination, for a distance of 500 feet or more, over the sliding rests of the back stay rod and the flags, and certain intermediate rests on the back leg of the tripod. With a little practice this operation was rapidly and accurately made, the several flags, rod, etc., being first put in line on the main base, so that the wire near the back stay was plumbed from a plumb-clamp over the stake and tack, which was the starting (or intermediate) point of measurement. The wire being in line, under a tension of about 300 pounds, a pine rod 12½ feet long, by standard, with brass butts carefully faced, was held under the wire with one end in contact with the face end of the plumb-clamp, and a brass clamp properly faced and sliding on the wire was put in contact with the other end and fastened by a hand-screw. A second sliding clamp was then put in contact with the first and fastened, the rod being relieved. This clamp then formed the starting point for another measurement of the rod on the wire, being relieved and brought up to the forward clamp and reset as the measurement progressed.

We had then an apparatus light, simple, easily transported, not easily injured, which three assistants could work in the field; a common spirit level sufficed for the wire in most cases, and in others, the notes were so taken that levels on the several stakes gave the data for corrections. Test benches of 500 feet were established, and the rod, in this way, frequently tested, and particularly after a wet interval, as it was soon ascertained that moisture was by far the chief source of any expansion.

In the more delicate processes of the Coast Survey, etc., temperature sometimes becomes a limit to work; in one scien-

tific description 100° is made the limit; but our work had to go on in the hottest and sometimes in the coldest weather. In former experience and an extended test here of the ordinary use of steel tapes or chains, it was clear without much study, that they were entirely unreliable in extremes; the same test however, fully vindicated the value of the wooden rods, as they needed care chiefly in wet seasons. We were embarrassed also by the continual necessity of educating new men, those used being mainly students of college or technical schools, who were anxious to acquire practice, and quite as ready to leave for any increase of pay. Under these conditions, I consider this system of measurement the key to the successful completion of our work in time, cost, and correctness.

The same rods were used from July, 1871, throughout the field work. Theoretically, the effect of changes in temperature, taking the modulus of steel, as adopted by the Coast Survey, at 0'.0000064 for 1° Fahr., and of pine (or deal) by Joule, at 0'.0000023, would be on 100° range, for 5,000 feet 3.20 feet in one case, and 1.15 feet in the other; practically, we found the changes of the rods slight, as a rule, in different seasons. For instance, Rod No. 1, on 500 feet test, January 9th to 31st, 1872, stood 0'.022 short (for whole distance); February 7th, 0'.0165; April 12th, 0'.023 long; May 8th, 0'.029 long. Rod No. 2, in August, September and October, 1873, ranged from 0'.010 to 0'.020 long, on various intermediate tests. In July 1871, a moisture test showed an expansion for a wet rod of 0'.500 in 5,000 feet; but as no measurements were made with a wet rod, our chief care was to detect the effects of absorption, which rapidly dried out.

In New Utrecht, 60th street was located parallel with 58th street, and made the base of the adopted system, and 86th street was established parallel with it, by measurements on 9th and 22d avenues, this parallelogram being the basis of included or extended bases from West street to 4th avenue. In making the check measuremant down 14th avenue base, from 60th to 86th street, the errror was 0'.04. on a distance of 6,940 feet; and the diagonal base measured down 4th avenue, also checked and proved the transit lines. On part of the Ocean avenue base line, a check measurement over a distance of 12,410 feet, by standard, came out 12,409.90.

In transit work, by using glass diaphragms in the instrument for intersections, which are much less subject to temperature and moisture changes than spider-lines or platina wire, and by care in multiplying or reversing sights, the work, in the hands of skillful assistants, proved very satisfactory, under severe tests, though carried on through all seasons.

In running the preliminary long, straight, base lines, I found no difficulty in using ordinary "railroad" transits. We eliminated all errors of collimation by double-reverse. Putting in the first

foresight on a stake from the first reverse, and then reversing the whole instrument for a second, back and foresight, gave us on the stake the entire collimation error, half of which furnished the continuation line.

Our measuring parties on favorable ground could run a mile a day.

The entire cost of the survey, with triplicate sets of maps filed, was about $73,000.

DISCUSSION.

G. M. Wisner: At the time of the work described by Mr. McElroy the engineer and surveyor used the now antiquated "surveyor's chain" for most of the measurements when approximate accuracy was required; but, of course, for the more accurate work, such as the measurement of base lines, a more precise means was employed. The steel tape, which has come into general use now, possesses all of the good qualities of the "surveyor's chain," being pliable and easily handled, and it does not have any links, which are apt to kink and be the cause of error, but is made of one continuous piece. Although the art of wire drawing has been known since the fifteenth century, the engineer seems to have been somewhat slow in his appreciation of its adaptability as a means of measuring, and it was not until 1878 that experiments were made with the wire or tape to be used as a measure. To Prof. Jäderin, of Stockholm, belongs the credit of making the first investigations with the tape. He began his researches in 1878, but his results were not published until his memoirs appeared in 1885. The essential fact developed by him was the effect of a change of temperature on the length of the tape. In the report of U. S. Coast and Geodetic Survey for 1893 there is a translation by Prof. Gore of Jäderin's paper on tape measurements.

The next we hear of the steel tape is its use by engineers of our own country, and what we of the West might be justly proud of, by the engineers of the western or central states.

In the summer of 1879, Mr. Alfred Noble and his assistant, Mr. Chas. Pratt, had to make the survey of about forty miles of the St. Mary's river, connecting the lakes Superior and Huron. The area to be surveyed was to be covered by triangulation. Base lines had to be measured and it was desired to do this more rapidly than could be done by wooden rods and more accurately than had been done previously on similar works by use of chains or tapes. An instrument maker was found who was prepared to make a tape 500 feet long, and this tape was used in the measurement of six bases or check lines during the progress of the work. In these measurements the tape was supported horizontally at intervals of 50 feet on pulleys 2″ in diameter fastened in the tops of heavy stakes; a tension was applied by means of a weight at one end of the tape, carried over a pulley 6″ in diameter. The distances were measured between center punch marks in the head

of a nail driven into the top of the stakes approximately 500 feet apart. The mean temperature was obtained by hanging two thermometers on the tape, the bulbs being wrapped with fine steel wire. The tops of the stakes were leveled for grade correction. The results of the duplicate measurements of the six lines were as follows:

No. of line.	First Measurement.	Second Measurement.	Discrepancy.	Ratio of discrepancy to length of line
1	2 219′.375	2 219′.025	0′.350	1:6340
2	3 122′.409	3 122′.425	0′.016	1:195100
3	7 127′.503	7 127′.595	0′.092	1:77460
4	9 116′.650	9 116′.807	0′.157	1:58070
5	3 044′.088	3 044′.075	0′.013	1:234150
6	7 990′.747	7 990′.721	0′.026	1:307300
Mean				1:146400

Probably on account of the lack of practice in use of the steel tape Messrs. Noble's and Pratt's assistants did not procure as good a result on the first measurement as in the last five, and in justice to the steel tape the first measurement should be thrown out, and then the mean of the last five would be 1:174400. The last two measurements are particularly good.

It probably did not occur to Mr. Noble or Mr. Pratt at the time that a greatly improved and substantially a new method of measuring secondary base lines was being inaugurated.

In the report of the Mississippi River Commission for 1881 there is published the results of some duplicate steel tape measurements made in 1880 the discrepancies of which are as follows:

1: 33000
1: 40000
1:180000
1:104000
1:333000
1:218000
1:200000
1: 59000
Mean, 1:145900

The method used is not described, but the engineer officer in speaking of the measurements says: "I will merely mention here what I hope to treat more fully in a special report—the unprecedented smallness of the discrepancy in the results obtained in measurements with the steel tape."

But it is not until 1883 that we find an engineer recommending the use of the steel tape for rapid and accurate measurements of secondary base lines. In the Proceedings of the American Society of Civil Engineers for 1883, in an article on "Geodetic Field Work," Mr. G. Y. Wisner recommends and describes the use of a 300′ to 500′ tape for the measurement of base lines for secondary

triangulation. The formulas developed are simple and if the tape is properly used the results are very accurate. The method used is to have the line to be measured staked out and the tape supported horizontally on stakes at equal intervals of about 25′. As better results can be obtained by measuring during the night or on a cloudy day, the stakes can be set during the day and the line measured at night. The proper tension is applied by means of an ordinary spring balance. The principal source of error is due to change of temperature. This is almost entirely overcome by taking two readings, one just before and one just after the measurement, with either two or three thermometers, wound with steel tape. The thermometers should be placed at ¼ to ⅓ the length from the ends of the tape. The object of having the thermometer bulb wound with steel tape is to prevent any "lagging," or to have the change in temperature effect the thermometer in the same manner as the tape. After taking the mean of the above readings the necessary correction is easily made. As the coefficient of expansion is given from 10.0000064 to 10.0000069, the error of one degree in the mean temperature would produce an error of about $\pm$ ½ inch to the mile, but with due care an error as large as this is not at all necessary. Another source of error would arise from not giving the tape the proper tension. The modulus of elasticity being 27,400,000, and the cross section of an ordinary tape about 0.002 square in., a change of tension of one pound would give a difference of $\pm$ 1 inch in measuring a mile. The length of the tape may be accurately determined by measurement of a known base with a uniform tension of, say 25 pounds, applied to the tape and corrections made for changes of temperature during the measurement. And then the engineer would not have to depend on any "standard."

Mr. Wisner concludes his paper by saying: "With proper care base lines can be measured with a steel tape as accurately as with a secondary base line apparatus usually used for that purpose."

In the Transaction of the A. S. C. E. for 1893 Mr. Woodward treats at length the subject of measurements by steel tapes and gives experiments made by him to determine the length of a tape. He used a bar of known length, imbedded in melting ice, to obtain the correct length of the tape, and as the bar was in melting ice it remained at a constant temperature, and no correction had to be made on account of the change of temperature. He came to the conclusion, after making several experiments, that error in the length of the tape could not be over 1:500,000, and that the probable error was only 1:2,000,000.

He also describes the measurement of a base 3870.5 meters long by means of a 100-meter tape. Five measurements were made, four at night, with temperature from 5° to 15°C, and one during the day, with temperature from 27° to 32°C. The range of the five measurements was 24.1 mm., or 1:160,000 of the whole length, or of the four measurements at night the range was only

18.5 or 1:209,000. The largest part of the error undoubtedly arose from an error in the mean temperature, although great care was taken to get the correct mean, three thermometers being used.

In volume XXX of the Proceedings of the American Society of Civil Engineers, Mr. J. A. Ockerson gives the following results of measurements of several different base lines with steel tapes, giving the error and the time taken for each measurement.

In August, 1880, a secondary base, 6663 feet long was measured twice with a 300-foot tape, supported at intervals of 25 feet. Temperature at the tape was about 94° Fahr. The discrepancy in the two measurements was 1:73,000. The time consumed for each measurement was four hours.

In the following measurements the tape used was 300.03851 feet long at 62° Fahr with a 16 pound tension. The size of the tape was 0.0246×0.1225 inches:

Place.	Year.	Length of base feet.	Time required for each measurement.	Discrepancy between two measurements.
New Boston, Ill.	1891	18,066	2 hours, 12 min. 2 " 12 "	1:759,000
Rapids City, Ill.	1892	5,624	41 " 28 "	1:594,917
East Dubuque, Ill.	1893	7,105	68 " 53 "	1:347,000
Cassville, Wis.	1893	7,001	47 " 37 "	1:266,412
Prairie du Chien, Wis.	1893	5,312	45 " 35 "	1:265,000

None of the above measurements were made while the sun was shining.

For measuring a base line like the above, it will require about 500 feet B. M. of timber and six men for two days to set stakes and grade per mile. Mr. Ockerson recommends that the steel tape should be adopted by all engineers.

Such engineers as O. B. Wheeler and Robert Moore recommend that measurements by the steel tape should be given preference over any other means of measuring. Mr. Moore says that wooden rods were recommended by a steel company to him for measurements in setting anchor bolts in foundations. He tried them, but had to give them up for the steel tape, which he found not only more accurate but a time saver.

In ordinary field work which you might call fairly accurate, I have seen a line 25,000 feet long, part of it through a swamp and the entire length through weeds and tall grass, with the temperature varying all the way from 50° to 90° Fahr., measured with an error of less than five inches, or which would be 1 in 60,000. The tape used was only 100 feet long and a commercial tape that had never been

carefully tested. The correction for temperature was only approximate. I have often thought that if we had had the proper means for getting the correct temperature, and had known the proper tension to apply, the error would have been much less, but it all goes to show that good and quick work can be done with the steel tape.

Coming down to a very recent date, a Mr. W. S. Dalrymple, Assistant Engineer, Board of Public Works, City of New York, describes a method of measurement by means of wooden rods in the Engineering News for May 19, 1898. The rod was made of straight grained pine with a brass frustum tipped with a polished steel end at one end, the other end was provided with a micrometer screw graduated to 5,000ths of an inch. Three rods were used and each rod had a battery for making an electrical contact and was also provided with a level. The lines to be measured were about 10,000 feet long and were carefully staked out, the stakes being 16 feet apart and provided with supports to sustain the measuring rods. The result obtained seems to be particularly good, the error in the field work being only 0.007 foot in 11,000 feet, or 1:1,571,000; but the method used evidently required considerable care, a large field party and consumed considerable time. The work described was commenced in April, 1897.

In the report of the chief of engineers, U. S. A. for 1897, Mr. E. E. Haskell describes the method used in remeasuring the Mackinaw base, four miles long, a line that was rather rough, the elevations varying from 11 feet to 68 feet above lake level. Mr. Haskell used three wires of No. 16 wire gauge, two steel piano wires and one of phosphor bronze, which closely resembles brass, but is more elastic. The wires were one kilometer long, with each 100 meter mark carefully marked on the wires. The object of using different materials is to obtain the correct temperature correction; for instance, for a change of temperature of one degree centigrade, a brass wire one kilometer long will change in length 19 mm., and a steel wire only 12 mm., a difference of 7 mm., quite an appreciable amount. The correct temperature is therefore easily computed. Brass, however, was found not to be elastic enough, and for that reason the phosphor bronze was used.

Each of the one hundred meter lengths of the three wires was carefully tested with a comparator on the canal grounds at Sault Ste. Marie, and experiments were made to obtain the correction for a variation in the temperature. A tension of 25 pounds was applied by means of a spring balance, a variation of one-tenth of an ounce in pull being indicated.

In the field work it required a party of nine men. They could stake out a kilometer of the line per day. Each of the three wires were carefully clamped, so that the zero mark was exactly over the starting point. The wires were supported horizontally every ten meters by hooks fastened by a silk cord, four feet

long, to crossarms of posts driven firmly in the ground. Five mercurial thermometers were suspended so that the bulb was in proximity of the wires, at the 100, 300, 500, 700 and 900 meter marks. The tension was applied by three spring balances and the distances were marked carefully on a metal plate securely fastened. In this manner ninety-nine sets of measurements were obtained, and it was possible to obtain two hundred measurements per day.

The probable error in the field work was about 1:10,000,000, and the probable error arising from the comparator 1:4,000,000, making the probable error in whole work about 1:3,000,000, a degree of refinement that had never been equaled before, I think.

A wooden rod, such as described by Mr. McElroy, is subject to a change of length due to a varying temperature the same as a metal tape or wire, and the coefficient of expansion is not as well known, although considerable smaller; and, as he says, its length is affected by dampness, whereas it has no effect on the steel tape except as it may cause a change in the temperature of the tape. Therefore, the tape would be preferable for measurements on a dewy night, which many engineers consider one of the best conditions for making a careful measurement. Again, no matter how carefully the rod may be clamped in position, when the forward rod is brought against the last placed rod, a slight jar is very apt to disturb the rear rod, thus causing an error. It seems to me that with the same care applied to a measurement by a steel tape as that used by Mr. McElroy with his wooden rod apparatus, that the result obtained should be more accurate, and certainly the amount of ground covered would be greater. In ordinary field work this would surely be the case with a green crowd of assistants. So it would seem that when fairly accurate, or even very accurate work, has to be done, the steel tape is the best known means as well as the most convenient, but of course, if a very high degree of refinement is required, then an apparatus such as that used by Mr. Haskell would be better. This, however, is simply a modification of the steel tape.

The President: The chair might add, in supplementing Mr Wisner's discussion, that in the last two or three years some very precise measurements have been made in the neighborhood of the Straits of Mackinaw by means of steel wires. These wires have the length of one kilometer, and there are two wires, one of phosphor bronze and one of steel; they were soldered together at one end, and the comparative readings at the other end of the wire indicated the temperature, the set of wires becoming a thermometer. These wires were supported at short intervals, 25 or 30 feet, and are subjected to a dead weight pull. The weight is attached to one end of the wire, and is carried over a wheel which has a bicycle wheel center, reducing the friction to a very small amount. By this method the probable errors in measurements have been reduced to much below one in one million.

ABSTRACTS OF PAPERS IN FOREIGN AND AMERICAN TRANSLATIONS AND PERIODICALS.

"STATISTICS OF GAUGINGS MADE IN THE PRINCIPAL BASINS OF FRANCE."

Abstract from an Article by M. BRESSE.*

(Published in the Annales des Ponts et Chaussees, 1897, Third Quarter.)

In this article Mr. Bresse commences by saying that his aim was not the inventing of new methods of gauging, nor the making of new experiments, but simply the compiling of the statistics of the results obtained.

The author further says:

In each basin we have kept separate, as particularly interesting, the information relating to the floods and to low water; further, whenever the gaugings were numerous enough at any one station, we have endeavored to establish a relation between the discharge and the height or the nearest gauge reading, and to express this relation by an algebraic formula as well as by a curve. Is is almost always possible to represent the discharge curve by the parabolic formula $Q=A+B\ H+C\ H^2$ by properly disposing of the three coefficients, and this is the form which has been generally adopted. Unless otherwise indicated H represents the gauge reading; but as the discharge at low water is particularly interesting we have in most cases put our formulas under the from $Q=A+B\ (H-e)+C\ (H-e)^2$, e being the positive or negative ordinate corresponding to low water, and consequently $(H-e)$ the height above the low water. Such formulas have no value beyond the value of the gaugings used in establishing them. If they have been sufficiently numerous, the accidental errors are eliminated, but if there should be a systematic error, like the inaccurate rating of the meter, or wrong selection of co-efficient, these errors will affect the formula.

Only an abstract will be given of the very complete and exhaustive statistics which follow, and of the methods used in obtaining the results.

THE SEINE BASIN — DISCHARGE AT EXTREME HIGH WATER.

During the flood of 1882 and 1883 observations taken on the Seine by means of floats, the tube of Darcey or the current meter of Lagrené gave the following results:

Flood of Dec., 1882. Maximum at Mantes: 7.54 m. (Dec. 8th and 9th.)

*Translated for the Journal by Mr. Ralph Modjeski, Mem. W. S. E.

Dec. 11, 1882: Below the mouth of the Eure (between Elbeuf and Orival, kil. 221), 2,483 cub. m.

Dec. 10, 1882: Above the lock of Poses (kil. 201.8) 2,246 cub. m.

Dec. 8 and 12, 1882: Below the lock of the Garenne (kil. 162.4), 2,363 cub. m.

Dec. 9, 1882: Above the lock of Port Villez (kil. 143.8), 2,149 cub. m.

Dec. 9, 1882: At Merincourt (kil. 120.9), 2,203 cub. m.

Dec. 9, 1882: At Rolleboise (kil. 119.6), 2,117 cub. m.

Dec. 10, 1882: Above the lock of Meulan (kil. 95.6), 2,128 cub. m.

Flood of January, 1883. Maximum at Mantes, 7.60 m.

Jan. 7, 1883: Below the lock of the Garenne, 2,240 cub. m.

Jan. 7, 1883: Above the lock of Port Villez, 2,141 cub. m.

Jan. 6, 1883: At Merincourt, 2,123 cub. m.

Jan. 6, 1883: At Rolleboise, 2,201 cub. m.

The principal information relating to high water in the Seine at and above Paris is given in the following table:

Place of Observation.	Date of Observation.	Locat'n of Gauge.	Gauge Reading.	Discharge. cub. m.	Remarks.
Paris between Bridges of Alma and Invalides.	March 17, 1876	La Tournelle	6.50	1,652	Floats. Gauging made during maximum.
	Dec. 10 1882	"	5.34	1,262	Floats. Gauging made three days after the maximum, water having fallen 0.50 at La Tournelle.
	Jan. 5, 1883	"	6.00	1,504	Floats. Gauging made during max.
Corbeil	Jan., 1883	Corbeil	4.30	1,263	Made during max.
Melun	March 1876	Melun	4.92	1,340	Floats. Maximum of flood. The flood of Sept., 1866, has reached at Melun 5.27 m. and the highest water known (1830) 6.38 m.
Bray between Nogent sur Seine and Montereau.	Jan. 2, 1883	Bray	2.91	430	Highest water known 3.13 m. (Jan., 1861).

GAUGINGS AT LOW AND MEAN STAGE OF WATER.

Seine: At Mantes the discharge curve has been platted from gaugings made at Triel and Manoir. These gaugings gave the following results:

Gauge Reading at Mantes.	Discharge at Triel.	Discharge at Manoir.	Gauge Reading at Mantes.	Discharge at Triel.	Discharge at Manoir.
0.57	133	...	2.23	466	...
0.75	149	...	2.86	...	553
0.84	...	172	2.89	609	...
0.85	172	...	3.40	716	...
1.05	...	209	3.90	920	...
1.18	244	...	4.85	1,101	...
1.72	...	363	5.15	1,221	...
1.76	353	...			

From these results Mr. Cheysson arrives at the following formula for the discharge curve:

$$Q=90\sqrt{(H+I)^3\ (0.62+0.05H)}$$

It was suggested to replace this complicated formula by a simpler one:

$$Q=71+110\ H+25H^2 \text{ (Lagrene)}$$

or

$$Q=170+150\ (H-0.80)+22\ (H-0.80)^2 \text{ (Preaudeau)}$$

For the discharges of the Seine at Paris Mr. Preaudeau suggests the two following formulas, reduced to the gauge of La Tournelle and to be applied only for gauge readings greater than 2 metres:

$$Q=110+180\ H+9H^2$$

$$\text{and } Q=70\sqrt{(H-1.80)^2}$$

These two formulæ, which give practically identical results, have been arrived at from gaugings by floats in Paris during the floods of 1876, 1879 and 1882–3, and at St. Cloud in 1876, 1877 and 1882. Their correctness has been confirmed by the high water of 1889.

In the parabolic formula the co-efficient of H^2 is relatively small. The straight line formula

$$Q=25H$$

gives results which are within 3 per cent. of those given by the parabolic formula.

A number of other similar formulæ for different points on the Seine are cited by the author also for the rivers Oise, Aisne,

Marne, etc. A number of plates accompany the paper of M. Bresse, showing the various observations and discharge curves platted as derived from the formulæ.

DISCHARGE AT LOW WATER.

The author cites some results of gaugings obtained at low water in the Seine, Oise, Aisne, Marne, etc.

THE MEUSE BASIN.

The method for this basin is here given in brief.

Discharge curves for a number of stations have been drawn from direct observations made with the wheel of Woltmann.

In addition to these, which we will call principal curves, a certain number of auxiliary ones were established for intermediate stations in the following manner: The discharge at the lower stages of water was obtained from gaugings at the nearest power plant; the rest of the curve was obtained by comparing the heights reached by various floods, with the discharges observed for the same floods at the two nearest principal stations. Mr. Mouton has figured by means of the discharge curves of the various stations the total discharge of the river Meuse during the flood of 1882–83, lasting from Nov. 1 until Jan. 15. Comparing these total discharges with the amount of rainfall in the watershed he obtains the following co-efficients or percentages of run-off:

Venloo (principal station)	0.73
Rurermonde	0.73
Maeseyck (principal station)	0.76
Maestricht (principal station)	0.73
Namur	0.78
Dinant	0.83
Hastiere	0.81
Stenay	0.76
Verdun (principal station)	0.83
Saint Mihiel (principal station)	0.84
Pagny-la-Blanche-Cote (principal station)	0.81

It was since deemed necessary to modify the original curves, owing to the recent construction of sewers.

This was done in the same manner as explained above with reference to auxiliary curves.

The author then gives various formulæ for discharge curves of the river Meuse at different stations, similar to those of the Seine basin.

THE MOSELLE BASIN.

At Epinal, Mr. Denys has calculated the discharge of the Moselle by applying the weir formula at the Champs du Pin weir:

$$Q = 0.40 \, L \, h \sqrt{2gh}$$

He then established a curve showing the ratio of the height h at the weir to the height H or stage of water at the Epinal bridge. He thus obtained a curve giving the discharges expressed in H; but he remarks:

1° That the curve of h and H is very imperfectly determined for all values of H smaller than one metre and consequently the discharge curve is no more exact.

2° That the coefficient 0.40 used ordinarily is very much too small when the weir is of large dimensions. He admits that the scale of discharges is really intermediate.

The author cites direct gaugings at this point and establishes some straight line formulæ giving better results.

At Remiremont no direct gaugings were made, the discharge curve was established in the same manner as at Epinal using a coefficient 0.654.

$$Q=0.654 \text{ L } h\sqrt{gh}$$

arrived at from the Epinal observations.

BASINS NORTH OF THE SEINE BASIN.

In speaking of the river Somme the author gives the following methods:

The Somme is interesting as having an exceptionally quiet flow.

The first gauging was made at Abbeville. Two cross sections were determined spaced 1,000 metres, after which the discharge was determined by the three following methods:

1° By means of the formula $R\,I = A\,U^2$ in which the value for A was taken $0.00028\,(1+\frac{1.25}{R})$ which applies to earth surface covered more or less with weeds. The discharge thus obtained was 74.573 cub. m.

2° By means of floats, measuring the surface velocity *in the middle of the stream* and taking four-fifths of this speed as representing the average velocity. The discharge thus found was 73.347 cub. m.

3° In measuring directly with Woltmann's wheel the velocities of the current on the surface, near the bottom and at half the depth on vertical lines spaced every two metres. The discharge thus obtained was 59.18 cub. m.

The author remarks that the method of taking

$$U=\frac{4}{5}V$$

where V is the average surface velocity and not the maximum is not exact. If we assume that the average surface velocity is four fifths of the maximum speed (which is confirmed by the wheel observations) we obtain the identical result with those of the third method. We may therefore assume that the discharge in this case was about 60 cub. m.

BASINS BETWEEN THE SEINE AND THE LOIRE.

The author indicates some very interesting experiments. Only one of the tables of results will be reproduced relating to the department of Orne which presents this particular feature that it contains the sources of all its streams.

The tables are averages for years 1875 to 1885 and cover the entire department:

Month of	Jan.	Feb.	Mch.	Apr	May	June	July	Aug.
Discharges of streams in millions of cubic metres....	272	327	264	208	130	101	74	58
Rain fall (millions cub. m.)...........	371	392	356	399	366	465	415	482
Run-of %.........	0.73	0.83	0.75	0.52	0.36	0.22	0.17	0.12

Month of	Sept.	Oct.	Nov.	Dec.	Warm Season May to Oct.	Cold Season Nov. to April.	Whole Year.
Discharges of streams in millions of cubic metres........	76	114	260	332	553	1,663	2,216
Rain fall (millions of cubic metres.)......	473	548	589	468	2,749	2,575	5,324
Run-of %.....	0.16	0.21	0.44	0.71	0.20	0.64	0.41

THE LOIRE WATERSHED.

The author describes the method used by Mr. Sainjon in determining the discharge of the Loire and its tributaries during the extreme floods.

The amount of water flowing uniformly in a rectangular channel of width l and grade i is given by the well known-formula

$$Q = l h \sqrt{\frac{l h i}{b (l + 2h)}}$$

in which b is a constant coefficent.

If the width is very great with regard to the depth, this formula may be written

$$Q = m h$$

m being a constant coefficent for each station. During the floods, however, the flow is not permanent, yet it is possible to determine *m* so that $Q = m^{\frac{3}{2}}$ will satisfactorily represent the variation of the discharge during a flood or even during various floods at the same point.

Mr. Sainjon has directed his studies to that portion of the Loire which is between Bec d' Allier and the mouth of the Cher, a length of 300 klms., on which length the river has no important tributaries, and has determined the coefficients *m* by remarking that:

1° The total discharge of a flood is constant over the whole section under consideration.

2° If two stations A and B be considered (A being up-stream from B), the discharge of a flood during a certain period, 24 hrs. for instance, will not be the same at A and B; it will be greater at A while the flood is increasing and at B while the flood is decreasing, and the difference will be the volume of water stored between A and B during the 24 hrs. if the flood is increasing or the volume of water which run off from that portion if the flood is decreasing.

This volume can always be calculated with sufficient approximation by means of observations taken at the gauges and by means of cross sections.

It results that if the stages of water at A and B are observed regularly every hour for instance, the discharge of A and B of a flood during any given period may be calculated in function of the two coefficients *m* and m^1.

The first remark furnishes only one equation, but the second one furnishes any desired number, because the beginning and the end of the considered period may be fixed ad libitum. Mr. Sainjon has shown that the coefficients *m* and m^1 remain always approximately the same and this justifies his hyphothesis on the shape of the dischage curve.

One coefficient *m* being determined for two stations, *m* for any other station may be found from the equation expressing the first remark.

If a tributary discharges between the two points considered, the total discharge of this tributary is equal to the difference of the total discharges of the river at the two points. But as the flood of the tributary is generally in advance of the flood in the river the discharge must be taken from the beginning of the flood in the tributary to the end of the flood in the river.

To make this method perfectly clear, the numerical example given by the author in the annexed note will be here repeated.

Let *m* be the co-efficient relating to A and m^1 relating to B; *h* and h^1 the corresponding mean depths, we have the two equations

$$(1) \qquad m \, \Sigma \, h^{\frac{3}{2}} = m^1 \, \Sigma \, {h^1}^{\frac{3}{2}}$$

the summation being extended for each point over the entire period of the flood;

$$(2) \qquad m \Sigma h^{\frac{3}{2}} - m^1 \Sigma h^{\frac{3}{2}} = \frac{V}{3600}$$

the depth h and h^1 are observed every hour; the summation being extended over all values of h and h^1 comprised in a period beginning and ending simultaneously at both stations. In this period V represents a volume stored or run off according to whether the flood is increasing or decreasing.

The co-efficients m and m^1 may be determined from the two equations.

For this first calculation, which was to be the foundation for all the others, Mr. Sainjon has chosen the section of the Loire between Cuissy and Orleans, 56 kilometers long, for the following reasons:

1° The Loire is thoroughly protected by levees on this whole length with exception of only about 1500 metres.

2° Besides two water gauges at Cuissy and Orleans there are seven intermediate ones, readings of which have been recorded during the flood of 1856, which furnishes the necessary data for calculating the volume V with sufficient approximation.

Let us suppose now that m and h are the co-efficient and the depth (or height) at Cuissy and m^1 and h^1 at Orleans In order to apply equation (1) Mr. Sainjon has taken the flood of May 20, 1856, and a period beginning at Cuissy on the 19th at 5 A. M. at stage 4.74 m. and at Orleans the same day at 3 P. M. at stage 4.50 m., and which ends twenty-eight hours later, or time after which the water at the two gauges came back to its original level, giving the same gauge readings.

We have for Cuissy:

$$\Sigma h^{\frac{3}{2}} = 288.21,$$

and for Orleans

$$\Sigma h^{1\,\frac{3}{2}} = 316.32,$$

Hence $288.21 \times m = 316.32 \times m^1$ or $m^1 = 0.91 \ m$.

In order to apply eq. (2) a period of twenty hours was taken, beginning at both places on May 31 at midnight:

We have for Cuissy:

$$\Sigma h^{\frac{3}{2}} = 252.06$$

and for Orleans:

$$\Sigma h^{1\,\frac{3}{2}} = 204.13$$

furthermore:

V=85,582,572.12 cub. meters:

$$\frac{V}{3600} = 23{,}772.94 \text{ cub. m.}$$

eq. (2) becomes:

$$252.06 \times m - 204.12 \times m^1 = 23,772.94$$

replacing m^1 by 0.91 m

$$m = 359 \quad m^1 = 326$$

During the period of 20 hours which was taken for applying eq. (2) the stage of water at Cuissy changed from 4.50 to 7.22 and at Orleans from 3.73 to 5.54. In order to verify the correctness of the assumption that m and m^1 are constant, the calculations were repeated in subdividing the 20-hour period into two of ten hours each, and it was found:

First period of 10 hours $m = 368$, $m^1 = 335$.

Second period $m = 354$,, $m^1 = 322$.

The differences do not exceed the limit of permissible errors in estimating stored volumes of water.

The coefficient of Orleans being determined the coefficients for any station between the mouths of rivers Allier and Cher were easily derived from eq. (1).

The author follows with numerous results of the foregoing method applied to the Loire and its tributaries, also other results by methods already described.

The paper is accompanied by a series of very interesting discharge curves.

GENERAL REMARKS.

Speaking of the practical value of the various methods of gauging, the author says:

In the first place all results obtained by means of hydraulic formulae giving the average velocity as a function of the grade should be discarded owing to the uncertainty of the value of the coefficients.

The only case where these formulæ may be serviceable is in case of rivers with regulated banks or levees, flowing in a very regular bed; even then it is indispensable to frequently check them by direct measurments of velocity.

The weir formula may give very accurate results, provided the conditions are such that the coefficient to adopt in the formula be well determined. M. Bazin (Annales des Ponts et Chaussees, 1888, 2d quarter, and 1890, 1st quarter) has shown that this coefficient may vary considerably; the weir method of gauging should therefore be applied only to small discharges, when a temporary weir may be constructed, similar to the one used by M. Bazin; the coefficient can then be defined quite accurately. We think, however, that serious errors may result from an attempt to apply this method to the large weirs in connection with the dams of navigable rivers.

The great advantage of Woltmann's wheel meter is that the velocity of the current can be measured at each point of the sec-

tion, which dispenses with the always more or less arbitrary coefficient; it has the disadvantage of being very difficult to operate in a strong current. Moreover, owing to the considerable length of time required to make observations, this method can only be successfully applied at low and mean water when the stage does not change rapidly.

At high water and especially during the extreme floods the only practical measurement of velocity is by means of floats. Either surface floats or ballasted rods can be used.

The method of surface floats has the advantage of simplicity and ease of execution; its disadvantage is the introduction of a somewhat arbitrary coefficient into the discharge calculations, which represents the ratio of the mean velocity to the surface velocity, and which is generally taken at 0.80. M. Bazin's experiments (Annals des Ponts et Chaussees, 1884, 1st quarter) relating to rivers of very different depths seem to prove that this ratio varies between 0.83 and 0.88. It would seem, therefore, that by taking 0.85 for this coefficient the relative error would be quite small.

On the other hand the ballasted rods give no better measurements of mean velocity. They must be shorter than the minimum depth of the stream and the error resulting therefrom may easily attain the error of applying the coefficient 0.85 to the surface velocity.

The surface float method recommends itself in all cases on account of its simplicity and rapidity of application. If a larger number of gaugings is required, those can only be made by men in regular service who are only moderately interested in the river discharge question. It is necessary, therefore, that a method of gauging be recommended which requires the least amount of outfitting and preparation, and for which no special knowledge or skill are necessary.

ABSTRACT OF THE MINUTES OF THE SOCIETY.

REGULAR MEETING—4th MAY, 1898.

A regular (the 383d) meeting of the society was held in the society rooms on Wednesday evening the 4th of May, 1898; President Alfred Noble in the chair. The minutes of the previous meeting were approved as printed. The chair by request appointed Messrs. Thos. Appleton and E. Gerber on the committee to assist in drafting resolutions on the death of Sir Henry Bessemer.

The discussion on fire-proofing previously announced was opened by Mr. Oscar Blumner, who read a paper on the subject. Mr. T. L. Condron followed with a verbal and a written discussion. Gen'l. Sooy Smith then stated his position at considerable length. Messrs. Frank B. Abbott, W. R. Roberts and others added to the discussion.

The paper on "Locomotive Water Supply" was read by T. W. Snow, the author. After brief discussion the meeting adjourned.

21st MAY, 1898.

OPENING OF THE NEW MEETING HALL

of the society on Saturday evening, 21st of May, 1898, took the form of a stereopticon entertainment, music and a sumptuous lunch, the latter served by Kinsley under the direction of our wide-awake, energetic entertainment committee. President Noble presided at the opening and Mr. W. J. Karner presented an interesting array of pictures of Cuba with brief pointed descriptions of customs and places. This was followed by the caterer's handiwork, and cheerful music enlivened the social intercourse. One hundred and sixty-five ladies and gentlemen were present and passed a delightful evening in the new quarters of the society. Palms and flags were tastefully arranged in the rooms and hall.

SPECIAL MEETING—MAY 18th, 1898.

A special (the 384th) meeting of the society was held in the society's hall on Wednesday evening the 18th of May, 1898; President Noble in the chair. The minutes of the previous meeting were read and approved.

The secretary reported the application of Mr. John N. Reynolds for associate membership.

Mr. Karner of the entertainment committee stated that the committee deemed the opening of the society's new rooms worthy of more than passing notice, and that they had arranged for a reception and entertainment for Saturday evening, May 21. All were cordially invited to be present with their wives, sisters and friends.

The first paper of the evening, "Gauging of Streams," by Wm. G. Price, in the absence of the author, was read by Mr. Condron.

Discussion was followed by the reading of the second paper "On the Use of Coke Breeze in Sewage Purification." The author, Mr. John W. Alvord, could not be present. Mr. Shields presented the paper. Discussion was taken up by Messrs. Williams, Wisner, Shields, Condron and Jonnston.

The meeting adjourned.

REGULAR MEETING—1st JUNE, 1898.

A regular (the 385th) meeting of the society was held in the society rooms on Wednesday evening, 1st of June, 1898; President Noble in the chair.

The minutes of the previous meeting were read and approved.

The first paper of the evening, "Obstructive Bridges and Docks of the Chicago River," prepared by Mr. G. A. M. Liljencrantz, was read by the author, and illustrated with a number of slides showing the various points of difficulty shipping has to encounter. The paper was one of unusual interest and value. Some thirty views of foreign water fronts, bridges, canals, etc., were shown at the close of the reading. Discussion followed by Messrs. Noble, Strobel, Condron, Gerber, Liljenerantz, Appleton, Tratman and others.

The next paper was on "Measuring Apparatus of Kings County Survey," by Mr. Samuel McElroy. The author being absent, the secretary read a portion of the paper, and the president described in a few words the method adopted for measuring distances twenty-five years ago in the survery related. Mr. G. M. Wisner then read a brief discussion, bringing the matter and means down to date. The president closed the subject with a description of recent improved methods. The meeting adjourned.

NELSON L. LITTEN, Secretary.

LIBRARY NOTES.

The Library Committee wishes to express thanks for donations to the library. Back numbers of periodicals are desirable for exchange and aid in completing valuable volumes for our files.

Since the last issue of the Journal we have received the following as gifts from the donors named:

W. A. Parker—Copies of Engineering Magazine, etc.
Michigan Engineering Society—Michigan Engineers' Annual, 1898.
University of Michigan—Calendar for 1897–8.
Boston Society of Civil Engineers—Constitution, By-Laws and List of Members.
Ira O. Baker—The Technograph, No. 12, 1897–8.
Imperial German Consulate, Chicago—Address-Buch Deutscher Export-Firmen, 1897, (Directory of German Exporting Houses).
Guide to the Export Industry—Saxony & Thuringia.
Reference Book, Mfrs. Saxony & Thuringia.
U. S. Dept. of State—Consular Reports, June, 1898.
Brotherhood of Steam Shovel Dredge Engineers and Cranesmen of America—Report.
U. S. Treasury Dept.—Report of Statistics on Lake Commerce.
U. S. Dept. Agriculture—Forestry Conditions and Interests of Wisconsin.
U. S. War Dept.—Test of Metals, 1896.
State of New Jersey—Railroad and Canal Reports, 1897.
U. S. Wind, Engine and Pump Co.—Catalogue Ry. Specialties for Water Service.
Lehigh University, Pa.—Register, 1897–8.
Civil Engineers, Cornell University—Transactions, 1898.
U. S. War Dept.—Preliminary Examination of Reservoir Sites in Wyoming and Colorado.
W. W. Salmon.—Zeitschrift des Vereines Deutscher Ingineur, for year 1897
C. L. Strobel.—American Engineer, Vol. 17 and 18, bound.
Capt. W. M. Black.—Corps of Engineers, U. S. A., Viaduct over Rock Creek, Dist. of Columbia.
Senator Wm. E. Mason.—Message from the President transmitting the Report of the Naval Court of Inquiry upon the Destruction of the U. S. Battleship Maine in Havana Harbor, Feb. 15, 1898, and testimony taken before the Court.
Otis T. Clapp, City Engineer.—Annual Report of the City Engineer of Providence, R. I., for 1897.
U. S. Bureau of Foreign Commerce.—Consular Reports, April, 1898.
U. S. War Dept.—Report of the Chief of Ordnance, June, 1897.
E. E. R. Tratman.—Administration Report of R'ys in India. Part II, '94–'95. Parts I and II, 1895–6.
Rose Polytechnic Institute.—16th Annual Catalogue, 1898.

TO MEMBERS.

The Library Committee wishes suggestions as to good engineering books, new or old, that are desirable for our library. The aim is to give the greatest good to the greatest number of our members possible with the funds at our command, and the committee, composed of few members, cannot well judge wisely to meet the various needs of our membership.

Will each member please send the Secretary of the Society the title of one or more books which he considers useful and authoritative in some line of engineering work? Please state title as fully as possible, together with names of author and publisher, etc.

Any suggestions in regard to the library in general or in any detail will be gladly received.

Journal of the

Western Society of Engineers.

The Society, as a body, is not responsible for the statements and opinions advocated in its publications.

Vol. III. AUGUST, 1898. No. 4

XXXIX.

LOCOMOTIVE WATER SUPPLY.

By Theodore W. Snow, Mem. W. S. E.

Read May 4th, 1898.

The subject of locomotive water supply is one of growing importance in this age of speedy transportation. No other branch of railway service has received so little attention in the past thirty years. It is not the purpose of this article to treat of its chemical analysis. It is conceded that like sundry beverages "some kinds are better than others."

The methods of delivery are varied and may be generally classed under three general heads, as follows:

First. From tank fixtures or sway pipes.

Second. From the standpipe, water crane, water column, or penstock, as this device is variously called.

Third. From the track tank, or "scoop" method.

(The steam syphon and other devices are not in general use sufficient to require mention.)

Of these devices the first is in most general use and admirably answers the purpose of speedy delivery when valve and pipe are of sufficient size. It is quickly operated and controlled by one man from the tender. The valve is protected by water within the tank from frost. The pipe is short and should be with but one long radius elbow.

The objections are the proximity of the tank to the track, where space is usually valuable. The duplicating of tanks on double track roads; the liability of catching fire in time of drought, and the careless drainage of sway pipe in cold weather and resultant iceberg adjacent to a rail.

This brings us to the second head, and the consideration of a properly-built standpipe, when the following conditions must be observed to get the best results, viz:

(a) Solidity of flow.

(b) Adaptable to single or double track.
(c) Entire operation by one man.
(d) Automatic return to position.
(f) Valve balanced to high or low pressure.
(g) Freedom from frost troubles.
(h) Ease of access to working parts.
(i) Freedom in rotation.

The speedy delivery of water is directly affected by these details, and in addition we have to consider the natural head, the pipe friction and the number of bends and elbows.

Where the railroad company is at the expense of pumping, it is desirable to keep the head low and to gain in discharge by increasing the diameter of supply pipe. Thus the fuel cost of elevating 1,000 gallons forty feet, is double the cost of elevating it twenty feet, and so on. It is important to determine the proper size of pipe and fixture and the following observations are offered by way of comparison with such tables and literature as are to be found relative to the subject in hand:

In designing a water station for one of our large railways recently, the problem given was to obtain 4,000 gallons per minute through a distance of 350 feet.

The head and size of supply pipe to be sufficient to accomplish this result. The mean head of water supply was made thirty-eight feet; from this must be deducted twelve feet for height of crane, leaving net head of 26 feet. In computing this flow an allowance of 10% was deducted for the friction of the water column. In figuring this discharge, Mr. E. E. Johnson's curve of discharge was used and comparing actual result with theory, we fell short only 400 gallons per minute.

This is pretty fair for practice, for considering that all table makers are careful to state that only "straight smooth pipes were used," (they want no "curves") we laymen have to make due allowance for the cast pipe of commerce, which usually is anything but smooth and not always straight. The bell and spigot connection causes considerable disturbance to the flow, setting up what in electrical parlance would be termed Fucault currents.

It may be interesting at this point to state a further observation:

In the station just referred to, the supply pipe was twelve inch diameter and the crane ten inches; the distance as stated was 350 feet and the discharge was 1,600 gallons in twenty five seconds, or at the rate of 3,840 gallons a minute. Under the same conditions with 1,000 feet of 12 inch pipe and a similar crane, this flow was reduced to 3,000 gallons per minute, due solely to friction. Comparing this again with Johnson's table above referred to, we find that we should have obtained 3,300 gallons.

Again with 350 feet of fourteen inch pipe and a twelve inch crane with three ninety degree elbows, we obtained a discharge of 3,500 gallons in forty-eight seconds, with a net head of twelve

feet. A comparison of same tables will show a uniform discrepancy.

Again on a recent test with an eight inch crane and 1,300 feet of eight inch pipe, under 125 pound pressure, the time of delivery was 3,500 gallons per minute. Consulting the same table we have as the theoretical output, 3,535 gallons. That pipe line is too smooth and straight and I have written for a verification and new time test.

Other tests show similar results, but this is sufficient for our purpose.

The objections are that the water crane is an expensive adjunct to a tank (most of the devices of this kind not being adapted to city water mains direct,) and they are time consumers, taking many minutes more than the direct method of using tank fixtures. This latter objection more nearly applies to the old time sizes of crane, viz: 4, 6 and 8 inch, as the foregoing results will show.

The third head refers to the track tank. This device was first used by the London and Northwestern Ry. some thirty odd years since, according to a recent article in the ENGINEERING NEWS.

It consists of a shallow trough about 18 inches in width and not to exceed 6 inches in depth and of various lengths, usually 2,000 feet. Every locomotive tender must be equipped with an inclined scoop or trough, mounted on the front end of which is a pony truck or pair of wheels to reduce friction and indeed to escape destruction.

The speed of the train is cut down to twenty miles an hour when taking water (or at least this speed gives greatest flow.) Time of delivery averages 3,000 gallons per minute and for fast express and limited trains avoids stops and is therefore quicker. The track tank costs about $1.00 per lineal foot, and in a recent instance was worn out by the trolley wheel in two years of servoice. Bottom plate was 5-16 inch in thickness.

The objections to it in this climate are that an expensive steam heating plant must be maintained in winter; also a gang of men to chip ice from the rail for the car wheel flanges. About as much water is wasted as is used, in the passage of the scoop.

There are two methods of warming the water, one by blowing live steam through it at intervals and again by placing a sump hole in the center and drawing the water through a suitable pump, forcing it through a heater and returning to the track tank at the ends.

DISCUSSION.

Mr. Thomas Appleton: Mr. Snow has given us some useful information in regard to the flow of large quantities of water in a short time. In railroad transportation it has become necessary to move passengers rapidly, and not only passengers but live stock and perishable freight, and it is found that the easiest way to

shorten the running time of trains is to reduce the time of delays. It is necessary to take a renewal of the water supply and a renewal of the coal supply on long trips, and if any method can be contrived by which water and coal can be taken quickly, the running time of the trains can be cut down. Railroads that use the old-fashioned six-inch water cranes or six-inch tank fixtures, and that use a half ton bucket handled by man power for putting coal into the tenders, cannot cut down that time as much as companies that have more modern fixtures. Mr. Snow has described how a flow of 4,000 gallons per minute can be obtained by using pipes and fixtures of the proper size and a suitable head of water; 4,000 gallons a minute is really a deluge of water. It is a great deal more than was ever contemplated by those who built the original water supply plants of the railroads. Probably there are more engines that take not to exceed 2,000 gallons than 4,000, so really the water supply of a locomotive can be renewed in half a minute, and one-half minute is not more time than is necessary for the engineer to go around his engine and oil up and look for hot bearings. It is really a very short time.

What Mr. Snow says about the difficulties of the track tank I think can be emphasized from experience in this region. In the first place, as he says, a great deal of water is wasted; it splashes over the sides as the scoop passes along and surges over the end after the scoop leaves the track tank. In winter this is disagreeable and dangerous. The water overflowing freezes, then more water freezes on top of this, so that in a short time a considerable iceberg is formed. It is absolutely necessary that the track should be exactly level, or else it would be impossible to keep sufficient water in the track tank. The splashing water and the heaving of frozen ballast requires that a thick bed of stone ballast should be used, and constant attention from trackmen is necessary to keep the track level and to remove ice in winter.

There is one other disagreeable feature that he did not speak of. A long open tank like this is liable to gather a good deal of dirt, cinders and floating matter, and this is scooped up into the tender, so the water would not be as clean as it would coming from a tank or through a stand-pipe.

Mr. Snow spoke of Mr. Johnson's formula or table. I was unaware that Mr. Johnson had originated such a formula. It seems to me it would be a good thing to show up that table or formula in the paper. If one of our members has originated a formula for the flow of water, he ought not to be allowed to hide his light under a bushel.

Mr. Snow: I would like to correct myself there. I had reference to the curve of discharge of which Mr. Johnson made a diagram and it was handy to refer to, and I think we gave him credit for his quick action device for getting at his discharges of water, and it was not intended to give him credit for the table, which was not his.

In regard to this time element, perhaps a little incident will prove interesting. Recently at Galesburg I was talking to one of the superintendents of the C., B. & Q. about the time of running their trains, and he told me that the locomotive department had gone just about as far as they could go with the locomotive, and that in making their computation for running through to distant points, and making as good time as their neighbors could make, every possible chance of getting half a minute here and a minute there was being looked to, and he mentioned this as one important feature. Their express mail train which leaves Chicago every day is fined, I think he told me $100, if it reaches Burlington five minutes late. Now, they have lots of passengers to take care of and lots of other business too, besides carrying that mail, and if they are late every day, $100 means a pretty good sum and somebody "up the ladder" begins to let them know they are there. They have to be late at times, and if the schedule is as fast as the locomotive can make, they have to make it up in some other way, and one of the ways that they take to make it up is to cut off most of the water supply. For instance, they had at one time between here and Galesburg six water stops, now they have one. At Aurora, where they had six minutes to stop for water, they cut it down to two, and this saving of ten to fifteen minutes gives them that much leeway to draw on, and if they are detained by any accident they know they may have fifteen minutes now where they had five minutes before, and that saves them this $100 many times. That is one of hundreds of examples that you have every day, and water is one of those problems that is important in getting people and mails across the country.

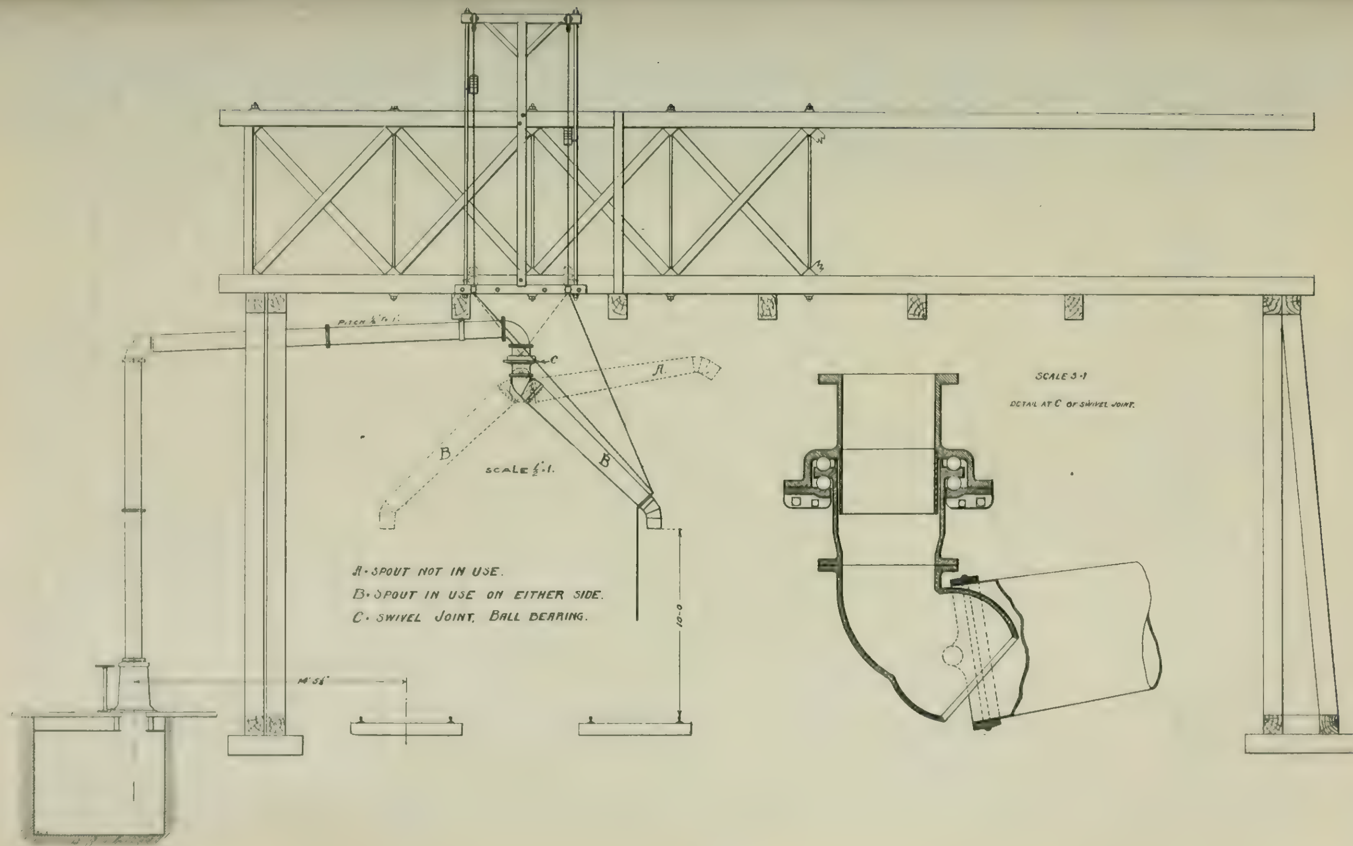
Mr. Appleton: I notice that Mr. Snow omitted to tell us how to get the water into the tanks in the first place. In his wide experience I presume he can cite some very interesting examples of "how not to do it," as well as give us his ideas as to how it should be done.

Mr. Snow: There is not enough time tonight to touch even one side of that subject. The railroads are using all kinds of machinery. I know some of our great railroads here running out of this city to whom we are selling material, use horse power machines and have for thirty years. They walk around a treadmill and elevate it in that way, and pay the driver thirty to forty dollars a month for this work. They are growing scarcer and there are very few of them left. The more progressive roads are using steam and other devices. On our western roads, where we have lots of wind, the water costs them next to nothing—perhaps fifteen or twenty dollars a year for all they use, we will say 100,000 gallons a day. At other important stations where they use more than that, and where they do not have the cheap and efficient service that they have out west, they use steam, gasoline, etc. The gasoline is a newer power and has only been

recently introduced among the railroads, and presents an endless amount of interesting matter, so much so that I hesitate to touch on that at all this evening. It is sufficient to say for those who are interested, that it is within the scope of any railroad company to elevate 1,000 gallons of water fifty feet high, which is about an average height, at a cost of about one-half cent, including fuel and the necessary maintaining, and everything that is necessary; that is, for every thousand gallons elevated fifty feet there is an expense of about one-half cent. I will say that the average steam cost of elevating water is perhaps three cents per thousand gallons. I will exclude those stations where they use upwards of two hundred thousand gallons a day, because there the steam cost becomes less, as the steam engineer's services present a smaller ratio to the number of thousand gallons pumped, but it is a favorable showing in any case, and it is one that is just being touched upon.

Fig. 413 is a drawing of a special adaptation of the Mansfield water column, which is something of a novelty. It was gotten up at the suggestion of an officer of the Pennsylvania road and is being put in for that company at the present time. The situation is as follows:

The coaling bridge outlined carries the coaling cars directly over four tracks. The engines are liable to stop at any time on any one of the tracks to take coal, and it is desired at the same time to take water at the rate of 4,500 gallons per minute, so that the two operations of taking coal and water may be completed in about the same time. As will be seen, the standpipes are placed without the tracks, presenting no interference to the operation of the crane. At the same time the spouts are free to swing 270°, and will automatically take their position parallel with the track and at a safe vertical elevation. This places the operation completely within the control of the man on the tender. The cranes are twelve inches in diameter and the usual precautions are taken against freezing. The universal joint for the sway pipe is sufficiently shown so that no further description is necessary.



PITCH ¼" TO 1'.
C
A.
B
B
SCALE ½"-1'.
SCALE 3-1
DETAIL AT C OF SWIVEL JOINT.
A-SPOUT NOT IN USE.
B-SPOUT IN USE ON EITHER SIDE.
C-SWIVEL JOINT, BALL BEARING.
10-0

FIG. 413.

XL.

A STORAGE RESERVOIR FOR A RAILROAD WATER STATION.

By Augustus Torrey, Mem. W. S. E.

Read August 9th, 1898.

One of the appurtenances for operating a railroad which the engineer has frequently to provide or care for, is a storage reservoir. This reservoir is apt to be somewhat out of his usual line of travel, and is in better favor with him if it or any part of it does not require much attention.

The reservoir is generally a small affair and quite frequently is dependent upon rainfall for its supply. With such reservoirs and with reservoirs for such purposes, generally the waste weir and apron are alternately wet and dry; more often dry.

It is a relief to the man responsible for a continuous supply of water and for immunity to his company against trouble, to be able to feel that the dam which holds back the water and the passages designed to take its surplus are in permanently good condition. Those of us who are heirs to reservoirs of this description have often been discouraged after viewing, so far as they can be viewed, the old cribs and other assemblages of timber and brushwood which answered well enough for dams and spillways in their youth, but which like other "ancient and holy things have faded like a dream," and come to us for our care and perpetuation in a decrepit state. The decision that an old dam is ripe for the sickle is a hard one to make, and the decision of how to replace it cheaply and permanently and without interruption of service is sometimes harder. A plan I followed in such a predicament may possibly be interesting. At any rate, it will not take much time to relate.

At the outset I wish to disclaim having made any new discovery; although the scheme was new to me, and since having thought of this as a subject of a short paper to our society, a limited research has failed to reveal its counterpart.

The dam setting back the waters of a small watercourse at St. Thomas, Ont., making an artificial lake of about fourteen acres, was about sixteen feet extreme height and three hundred feet in length. Near the center of the dam was a crib, at one time more or less filled with brush and clay and topped with a plank floor over which the waste water ran in freshets. The side or end walls of the crib were extended above the level of the floor so as to give an available waste weir of 26 feet by 2 feet. An apron supported on timbers conducted the waters to the old creek bot-

tom. This flume had an inclination corresponding to the repose of the earth which constituted the remainder of the dam. The whole affair was old when I first saw it, and exposure to water and sun had cracked and decayed the timbers so that, in spite of the many battens on the floor of weir and apron, much water gurgled in the bowels of the crib. The timbers carrying the floor and presumably the lake were moss-grown sepulchres. It was clearly a difficult matter to replace the structure in its original form, and I decided to cut loose from such ideas of waste weirs as I knew of and had seen, and to utilize the force of the flood in taking itself beyond the dam. I lowered the pond about four feet by temporary means, which exposed the bottom for about 20 feet inside the high water shore line. I sunk without difficulty on this exposed lake bed a cylindrical caisson fourteen feet in diameter, made of three-inch plank sixteen feet long. I excavated the earth inside this caisson and built therein a basin out of concrete, cylindrical outside and in the form of a frustrum of a cone inside. The bottom was three feet thick. The lower inner diameter was five feet and the upper inner diameter was ten feet. The walls reached within two feet of the top of the dam. An iron pipe 36 inches in diameter was built into the side wall of the basin at the bottom of it and led through the end of the dam to a discharge near the old creek bed below the dam. The pipe was caulked with lead and held together with rods. I removed all the timbers I could from the old waste weir, filed the hole with clay, and serenely waited for the next storm. All the more serenely because I had used a 36-inch pipe, while I knew a 30-inch under 12 feet head would carry all the water which the old waste weir would accommodate. At last the rains descended and the floods came, and with them the farmers from far and near, who were eager to see the 26 by 2 camel go through the 36 inch needle's eye. That waste weir entertained the visitors with music and contortions beyond the wildest speculations of anybody. Its roarings could be heard for miles, and the alternate sucking down of the flood and vomiting of it forth were features in a waste weir too new to be entirely satisfactory. The pulsations of the discharge of course interfered seriously with its volume, although I think their violence would have abated had the storm raised the pond the other ten inches there were to spare.

The waste weir was too much of a howling success to be proud of. The flat bottom of the basin clearly stopped the movement of the column of water until it could get a considerable head. Immediately after that first storm I filled the bottom and sides of the basin with concrete, and now it is funnel-shaped with a curved neck joining it to the level pipe. The floods which have come since have flowed over the edges of the basin and converged into the neck as smoothly as a train enters a curve, which is linked to the tangent by a spiral, and which is elevated to suit the align-

ment. I should judge that the maximum head on the pipe had been about eight feet. As the waste weir stands at present it seems to be efficient and permanent, and I certainly should not hesitate to adopt as an economical device a similar construction on a much larger scale. An earthen dam is in most cases a secure and imperishable dam if the waste weir does its work; and this kind of waste weir will do its work if properly proportioned. The force of the discharge is the only destructive agent present, and that can be spent on boulders remote from the foot of the dam.

XLI.

PARK BRIDGES.

By OSCAR SANNE, Mem. W. S. E.

Read July 6th, 1898.

Some years ago I was requested by Mr. Christian Wahl, president of the Park Commissioners of the city of Milwaukee, to prepare designs for park bridges which should fulfill not only the engineering requirements, but would be designs in every respect of the highest artistic value.

It is true not very often an engineer has an opportunity to exhibit more than what is called the practical side of his profession; it was, therefore, a great pleasure to me when I was called upon to do work more in the artistic line, and I think the more our country is settled and people commence to enjoy life and look more for an æsthetic development there will be a growing demand for a combination of engineering skill with highly artistic achievements.

During the last five years I have designed and built for the Lake Park of the city of Milwaukee several ornamental bridges. Starting with a simple foot bridge, built as a viaduct over a very picturesque ravine, I have gradually developed a system of park bridges which are not only strictly engineering structures, but which have been very carefully laid out with the view of obtaining the most pleasing artistic effect.

To obtain this result it is necessary that the engineer, being entrusted with such an unusual task, should carefully study everything about the laws of beauty when applied to construction. To show a steel structure in the most beautiful harmony of its details is often more difficult than to solve the most complicated mechanical problem. This kind of engineering work cannot be done in a rush or by the thumb rule, but requires careful and thorough study of every detail; all proportions must be well weighed, so that a pure harmony will prevail in the whole as well as in its parts.

The development of the artistic side of the engineering profession meets to some extent with difficulties which the architect does not experience. The latter has any amount of very excellent examples from ancient time; they form the very best guides for him and with their help his way to highest perfection is comparatively smooth. Not so with an engineer. There are very few examples of important engineering structures where the lines of beauty play such a prominent part; our way of construction has been changed so very remarkably that hardly anything now can be compared with the construction of ancient time.

Construction in steel and iron, for instance, has been developed to such a high degree of practicability, based upon such profound scientific principles, that the engineer of our days is in a position to solve most any problem, and yet how little attention is paid to the artistic effect of any of the more important structures, which are not always located in the midst of the wild prairie, but very often in the heart of our larger cities, and which are without question examples of the highest engineering skill, but which bear only too often testimony of a very poor and sometimes vulgar taste.

We very often hear the argument that those structures shall only answer the requirements of utility, any ornamentation or beauty being considered a waste of money and time. This seems to me a very shortsighted argument. Even a bridge, for instance, well designed and laid out with care and due attention to harmonious effects, will make a noble and pleasing impression, and does not generally cost more than a bridge simply constructed according to a strain sheet without the slightest attempt to produce pleasing proportions and harmony of details. Such a structure may call forth admiration for the bold designer, but will never appeal to our sense of the beautiful.

What is required to improve on our present designing of bridges and similar structures, in order to make these structures of most attractive character and artistic appearance, so that such a structure would be a precious treasure for the noble and beautiful surrounding, is, in the first place, that the designer takes the necessary care, love and thoughtfulness in working out a design in harmony with itself and its surroundings. Not too much time can be spent on a drawing board, if the designer is called to bring forth even in an engineering structure the fullest harmony and purest lines of beauty. It takes study to find out why certain ornamentation is wrong, or why a line of construction is just the right thing for the sake of beauty. It should be the duty of every student of engineering science to develop besides his judgment for correct design, a taste for beauty in a structure. That personal gifts play a great part in this requirement is undoubtedly true, but in our day there are plenty of men of talent who never get a chance to develop these precious gifts and their sense of beauty is gradually dying away.

My endeavor has been to create structures in our Milwaukee Lake Park which are in full harmony with the beautiful and superb lay out of this park, which in time to come will be one of the handsomest in this country.

Not only has nature given us the most attractive and picturesque scenery along magnificent Lake Michigan, where beautiful ravines change with rich meadows, bordered with majestic groups of the finest species of forest trees, but careful and thoughtful landscape engineering has assisted nature in bringing forth the most magnificent park that can be found anywhere.

The first three bridges built during the years 1892 to 1894 are shown plainly in Figs. 414, 415, 416. They are noble looking structures, showing the greatest harmony in their proportions. The foot bridge, Fig. 414, is not very richly decorated, but considering the limited amount available can be classified among the handsomest of its kind.

This bridge is composed of 2–30 feet and 1–50 feet plate girder deck spans; the girders are 30 inches back to back of angles; this depth was considered the most effective one with regard to graceful appearance. The girders are placed 12 feet 9 inches center to center leaving a walk of 12 feet clear between handsome iron railings; the bridge has two bents of ornamental cast iron columns well braced. The abutments are made of well bonded limestone masonry, with a very effective ornamental hand-railing of terra cotta on top of coping. The contemplated flower vases and lamp-posts, as shown on the design, will greatly improve the appearance of this bridge.

The cost of this structure was as follows:

For the masonry and terra cotta railing.....	$1,398.45.
For the iron work..............................	1,274.00.
Total..................................	$2,672.45.

My total estimate was $3,000.

The second bridge, Fig. 415, is a 50 ft. steel arch. This bridge carries the park driveway over a very picturesque ravine.

It is composed of 6-50 ft. steel arch ribs, very thoroughly braced; the front ribs are very effectively ornamented by a cast iron ornamental cover. The four inner ribs are made of 4-3″ x 3-1/2″ x 3/8″ angles and 1-18″ x 5/16 web plate; the two outer ribs of 4-3″ x 3-1/2″ x 5/16 angles and 1-18″ x 1/4 web plate. The ribs were calculated and constructed as arches with two hinges; they were figured for a live load of 100 lbs. per square foot plus the dead load. The floor was figured for the same load. In addition to same a ten ton roller was assumed.

The roadway is 26 ft. wide, resting on a floor support of I beams and buckled plates. The roadway is composed of about six inches concrete, on top of which are laid 5″ asphalt paving blocks. The sidewalks are 7 ft. wide, resting on I beams, and are made of 3/8″ cast iron plates with diamond face. A handsome handrailing thoroughly connected to the outside girder helps greatly to the pleasing effect this bridge produces.

The abutments are of the U shape, with very heavy buttresses for each arched rib. A handsome terra cotta handrailing is placed on the top of coping.

The appearance of this bridge will be greatly improved by putting the handsomely designed flower vases and lamp-posts in their proper positions.

The cost of this bridge was as follows:

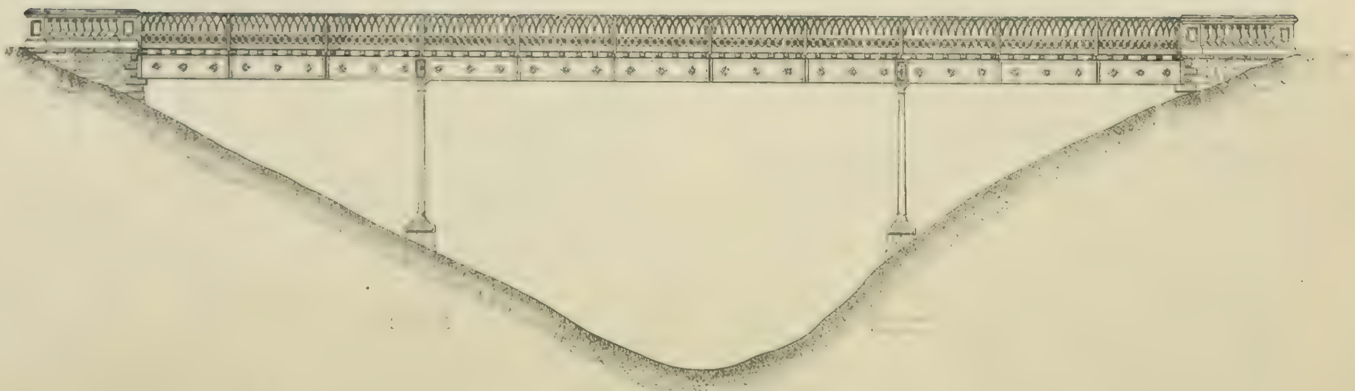


FIG. 414. FOOT BRIDGE AT LAKE PARK. Two 30 foot Spans; One 50-foot Span.

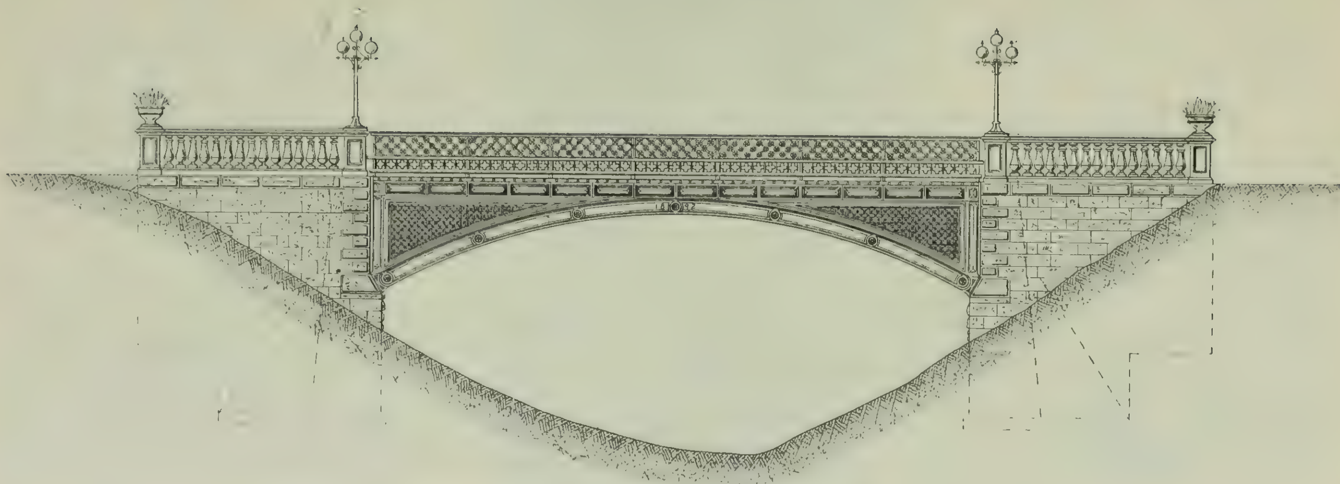


FIG. 415. BRIDGE OVER SOUTH RAVINE, LAKE PARK. Arch, 50-foot Span.

Masonry and terra cotta	$5,786.00
Iron work	4,265.65.
Roadway floor and sidewalk	769.83.
	$10,821.48.

Estimated cost was $11,200 00.

The third bridge, Fig. 416, is a 35 ft. brick arch over a very beautiful ravine. The ornamental parts of this arch were made of terra cotta, also the face stones of the arch proper. The arch is made of five rings best sewer brick, laid in Milwaukee cement. The face of the spandrel and wing walls were laid with handsome brown-face brick.

FIG. 416. A 35-FOOT BRICK ARCH BRIDGE.

The sidewalks, 6 ft. wide, are made of concrete, and the roadway, 26 ft. wide, of Macadam.

A fine ornamental handrailing of terra cotta gives this structure an elegant finish.

This bridge will also be greatly improved in general appearance as soon as the lamp-posts are in place.

The total cost of this bridge, which was let in one contract, was $10,449.00. Estimated cost, $10,800.00.

The most attractive and highly artistic of all the bridges in this park, however, are those located near the Government Lighthouse, crossing two of the most picturesque ravines, with a fine view over the magnificent bay of Milwaukee.

These bridges form the main entrance to Lake Park and are located in the most desirable residence property of the city of Milwaukee.

It was, therefore, very natural that these structures received the greatest care and attention as to proper harmony in their

FIG. 417.—BIRDS' EYE VIEW OF LAKE PARK, MILWAUKEE. Showing location of two 87-foot Steel Arch Bridges.

details. It required a great deal of study to give them the most attractive and artistic appearance, and I may add that only the desire to create something worthy of admiration by lovers of art was the principal motive that guided me in the design of these bridges.

After a careful investigation of the peculiarities of the location, with due consideration of economy and utility, I concluded that the most satisfactory solution of this problem would be the adoption of an arch bridge.

The accompanying drawings and photographs, Figs. 417, 418 and 419, show the manner in which the whole design was treated, and also give a clear conception how beautiful these bridges look in the reality.

I have tried to work out an ornamentation which will closely follow the construction; there is not a detail or ornament in the whole design which would be superfluous. I avoided all bric-a-brac work and utilized all the different parts necessary for such a structure as ornaments.

It required a great many sketches to produce the most pleasing effect in the distribution of the masonry and iron work; these two important parts have to be in very harmonious proportion to give the most effective impression. I hope that my endeavor may be crowned with success. Of course, everything we put on the public highway in the form of structures is open to criticism, and I am well aware of the fact that there may be many artists who have a different idea as to the requirements of such structures. However, I am conscious that I have tried my very best, but I shall be only too glad to receive just criticism. Any hint by which I could in future improve my designs will be accepted with great appreciation and thankfulness.

These bridges were started in September, 1896, but owing to some difficulty in getting the proper stones the work was badly delayed and the stonework was not finished before the beginning of October, 1897. The foundation of these bridges offered no particular difficulties; the bottom consisted of a very solid clay ground upon which the footings could directly be laid. To get a better distribution a layer of two inch sand was put under the footing course. The allowed pressure at the ground was two and one-half tons per square foot. The foundation course consisted of selected stones not less than twelve inches thick. Masonry above foundation and below surface of ground was laid in well bonded rubble masonry, above surface of ground ashlar masonry with rubble backing was used. Stretchers were not less than eighteen inches thick and each course of the same thickness of sixteen inches above skewback. Below skewback the stones varied from sixteen to seventeen inches in thickness. Practically the stones had all to be cut stones with one inch chisel draft.

The walls were provided with weepholes well filled with broken stones for the purpose of drainage; the filling behind the walls was done with cinders about three feet thick.

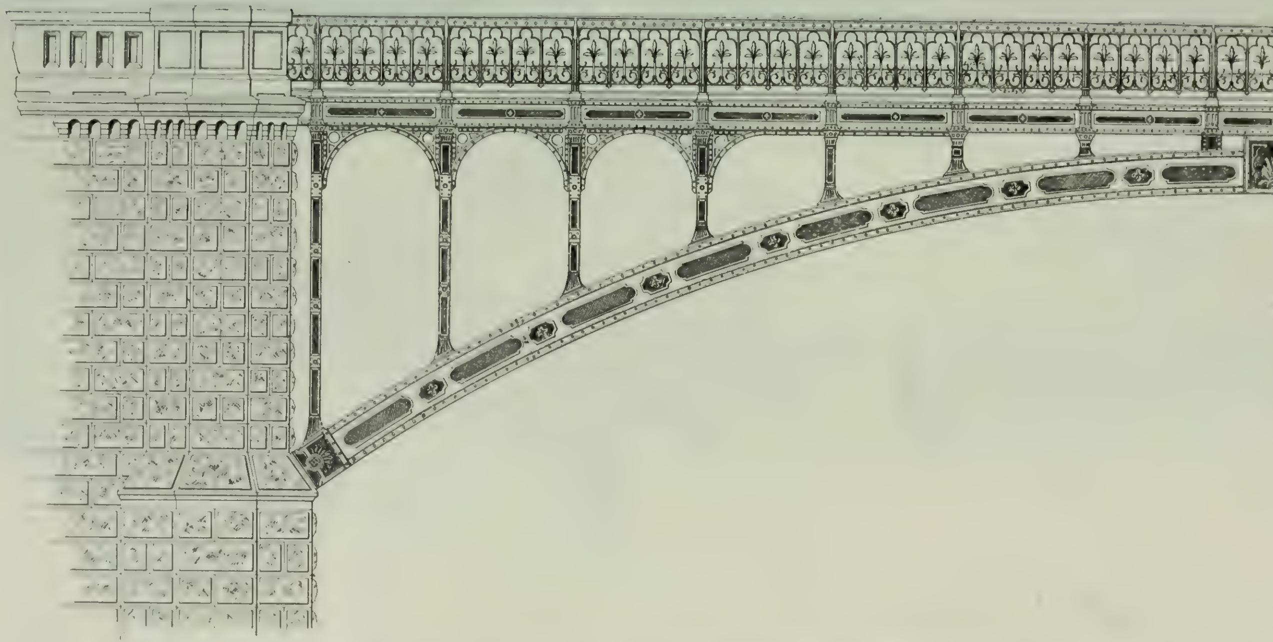


FIG. 418.—DETAIL ELEVATION OF OUTER RIB FOR TWO 87-FOOT STEEL ARCH BRIDGES IN LAKE PARK.

FIG. 410.—87 FOOT STEEL ARCH BRIDGE IN LAKE PARK.

The four abutments were laid with the utmost care, and every precaution was taken to conform in every respect with the detail drawing.

The iron work was built by the Wisconsin Bridge & Iron Co. The detail work was laid out under my personal supervision. The accompanying plans and photographs give a very clear idea how the details for this bridge were designed. I wish only to mention that these two arch bridges were calculated as two hinged arches for a load of 100 lbs. per square foot plus all the dead load. The floor proper was designed to carry a concentrated load produced by a steam roller of about sixteen tons. In the calculation of these arches the effect of temperatures was also considered.

In this whole design I have endeavored to get out the shop details as simple as possible, yet always keeping in consideration their most effective appearance.

I have not provided in these bridges for lateral nor sway rods, but have used 5-16 inch gusset plates and have placed my cross struts at each panel point. The posts are simply set on plain cast iron shoes securely bolted to same. The floor of the roadway and sidewalks is carried by I beams, upon which rests buckle plates one-quarter inch thick. The appliance of these buckle plates gives the bridge an enormous lateral stiffness.

The roadway was made of about a layer of four inch best Trinidad asphalt resting on concrete three inch layer; the sidewalks of the very best Atlas cement concrete.

It is very encouraging to see how perfectly this concrete followed all the motions produced through expansion and contraction of the bridge; no cracks whatever have been observed.

The iron hand railing is partly made of steel and cast iron, the ornamental part, which was originally designed for forged material, has been very successfully made of cast iron.

Due allowance was made on these handrailings for contraction and expansion by putting the ends of the railings into a pocket chiseled into the stone railing for this purpose.

The abutments are finished by a very effective cornice of two feet depth, and on top of this is put a plain but well-proportioned railing. These two parts were originally designed for terra cotta, but as the cornice and railing could be obtained in Bedford sandstone for about the same price as the lowest terra cotta bid, it was concluded to use blue Bedford sandstone.

When I first designed these cornices and handrailings I intended to bring out the most effective lines by using a considerably darker color in the terra cotta, but the Bedford sandstone is fully as decorative through its dark bluish appearance as any terra cotta would have been; besides it is very evident that terra cotta will never be gotten out in such large pieces and therefore will always make it appear too much like piece work.

On the top of the half octagon of the handrailing is placed an ornamental lamp post with five lights.

These bridges are effectively ornamented by artistically sculptured stone lions resting on heavy pedestals.

So far the bridges are finished, but they will be greatly improved in appearance by placing the ornamental posts and chains between the open space left, as can be seen on my first design. I have no doubt that as soon as the ground is properly graded and sodded around these bridges that they will make a very noble and elegant appearance.

The ornamental lions for this bridge were donated by Mr. H. C. Payne of Milwaukee and sculptured by Mr. Paul Kupper of Milwaukee.

In order not to make my paper too long and wearisome, I will close with a few remarks as to the conditions under which an engineer who has a desire to develop the artistic side of his profession has to struggle. In the first place, it is a great pity that the public in general takes so very little interest when the question of embellishing a city or park arises. If the people could be awakened to appreciate more fully what the conditions really are, it would be much easier for the professional man to develop this special branch of engineering. Even architects are confronted with so much ignorance on the part of the public that they are greatly hampered in carrying out their artistic ideas. This is more the case with the engineer, of whom seldom anyone expects more than his name indicates. It, therefore, gives us a great deal of joy when we meet among unprofessional men one who understands our artistic aim, and whose judgment is guided by rich experience gathered through traveling all over the globe. Such a man was the President of the Park Commissioners.

Let us hope that people will become better acquainted with the rich treasures of art in this beautiful world, so that engineers and architects will always receive the fullest support in carrying out their artistic ideas.

DISCUSSION.

A Member: I would like to ask Mr. Sanne about the color of the iron work of the bridges.

Mr. Sanne: The color of the bridges is black (graphite paint) which is very effective. We give the whole bridge one coat of black, the ornamental casting standing out very clearly.

When I made the designs of these castings, they were simply for cast iron plate with regular diamond face, and when I went to the shop the patterns were not diamond faced, but something similar, and I was foolish enough to allow them to use them. I regret this very much, because the effect of these bridges would have been much greater if it had been made as I had designed.

Mr. W. H. Finley: I would ask why you use cast iron at all?

Mr. Sanne: In the first place, when I designed these bridges I started with open spandrels and wanted to build up a sort of a post, so as to get a most pleasing effect for the rail. I wanted to have castings to show a support for my railing, and also a support for the column and arch; that would have been all right. I could have done away with the rest of the castings, but the trouble here was a big flue resting on the arch-rail that would have been very ugly. I do not consider the castings first-class myself; the thought came too late after the material was ordered and all the patterns made. I will tell you one thing—it has been suggested that I was wrong in leaving out the sway rods and lateral trussing, but I made it this way: Where the post strikes I have a very heavy strut made out of $2\frac{1}{2}''$ by $2\frac{1}{2}''$ angles, and connected these struts to each rib by double truss plates, and it makes it appear from below like the ceiling of a room, with ornamental panels. I was under the bridge when a big wagon went over rapidly. I was holding on to a truss and did not feel the least bit of jar. That shows that the construction is strong.

Mr. Finley: I saw those bridges Sunday, and they make a very pleasing appearance. To go back to the ornamentation, Mr. Sanne has designated a cast plate that gives the appearance of a keystone in a stone arch. I think that detracts very much from the appearance.

Mr. Sanne: To be honest about it, I pitied myself that I did it, but it is too late now. I thought really by doing that I would make it more interesting, that was the main idea. This whole ornamentation does not figure so much in any structural way, you might say. I should have left that keystone out entirely.

Written discussion by Ralph Madjeski, *M. W. S. E.*

In his very interesting paper Mr. Sanne justly points out the increasing necessity for the engineers to study the æsthetic side of structures especially in more populated districts. There seems to be a prevalent idea among even some of the best engineers of our country that the addition of a few cast iron stars, bent bars, perforated plates in the portals or corkscrews on the hips will make any bridge look handsome. If the skeleton of the bridge or of any structure is not designed æsthetically, such petty ornaments only make things worse and should always be discouraged. It is impossible to take the skeleton of a hunchback and make an Apollo of him by covering it with any amount of beautiful flesh and skin. If a structure is to be beautiful its æsthetic side must be given equal importance and attention with its stability. Both have to guide the designer from the very conception of the project; the skeleton must be built in harmony with the ornaments.

The criticism raised by Mr. Finley at the meeting regarding the

ornament in the shape of a keystone is, I think, correct. While in a masonry arch a keystone may and often does look very well as being appropriate to that kind of construction, a keystone in a steel arch gives an impression of something superfluous and its omission would have been an improvement. One other thing does not, in my opinion, produce the harmonious effect that it should, and that is the upper portion of the spandrels. The three first panels from the abutments are crowned with a semicircular arch, the fourth panel has only one-half of an arch, and the center panels are rectangular, having no arch at all. The center panels, as a matter of course, do not admit of a semicircular crowning, but it seems to me that the detail could have been arranged so as to present a similarity of panels and avoid the somewhat sudden change of form and the appearance as if something were missing in the panels near the center. Mr. Sanne places his outside arched ribs under the railing. This is right, but is not always done. I have seen arch bridges with sidewalks placed on projecting brackets, overshadowing elaborate arched ribs. This Mr. Sanne has very wisely avoided. This idea in leaving the braces between spandrel posts and arches as open as possible is a very good one.

XLII.

A COMPARISON OF THE HOLLOW BORED METHOD AND THE FLUID COMPRESSION HOLLOW FORGED METHOD OF MAKING STEEL FORGINGS.

By GEO. H. BRYANT, Assoc. M. W. S. E.

In presenting this paper before your society it is not my intention to deal in detail with the many processes of manufacturing hollow bored shafts and steel forgings, as the various methods have previously been extensively presented and discussed.

Some of the papers, however, I believe, have laid too great a stress upon certain processes that are more to the advantage and benefit of the producer than to an increase in the merit of the finished material produced, and it is my intention to show why the Krupp Works, after having experimented with the different processes, adhere to their present method.

The process that has been most thoroughly and elaborately submitted is undoubtedly that used to produce fluid compressed steel, and the Krupp Works a number of years ago made extensive and careful experiments with this method of making ingots for heavy forgings, and it is a noticeable fact that today they are using their method of casting a larger ingot than is cast by other manufacturers, and do not in any way use the fluid compression.

The Krupp ingots, however, are cast three times the diameter of the finished shaft, while the most modern works cast ingots of but twice the diameter the shaft is to finish.

Segregation, of course, takes place in the centre of every ingot, large or small, and as is admitted by the advocates of fluid compression, is not prevented by that process.

Further on I will state how piping is prevented by the Krupp method, but first I will say that a longer section of an ingot can undoubtedly be used for the forging by the steel maker using the fluid compressing process, for the hydraulic pressure must force the gathering air or gas cells higher in the mould than the ordinary static pressure does. This is an economical result, however, of benefit to the manufacturer only, the character of the material in the melting charge and the subsequent forging and treatment being responsible for the character of the finished steel and its merit.

For many years the Krupp Works, and recently most of the works in this country, have used hydraulic forging presses for the manufacture of the largest shafts, as the material can be

thoroughly worked by this process only, being a most important point for the strength of the shafts, and for this purpose the Krupp works at the present time are equipped with a large number of hydraulic presses of different capacities from very small up to those of 5,000 tons effective power.

At the Krupp works, as above stated, the rule observed is that the diameter of the ingot must be three times the diameter of the finished shaft, while it is understood that the most modern works in the United States forge from an ingot but twice the diameter of the finished shaft. By the Krupp rule an ingot is drawn out to the high degree of 9 to 1 as against 4 to 1 by the process employed in this country.

At works which forge hollow, a hole is bored through the ingot of the diameter of the bore of the finished shaft, consequently necessitating the cooling down of the ingot before being forged.

Even if the ingots cool down very slowly, this method nevertheless, involves considerable risks, as the strains which are unavoidably produced in the ingot, in this condition of largely crystalline structure, are likely to cause cracks. The reheating of the ingot is for the same reason unreliable, even if the greatest care be taken.

For these reasons at Krupp's Works all large ingots for shafts and other heavy forgings are never allowed to cool down after casting, nor during the process of their manufacture, but are kept hot until the working of the forgings under the hydraulic presses has been completed.

By working the ingot from its original heat the detrimental effects from piping are removed, as the strains causing piping are not allowed to generate, owing to the working from the hydraulic press both by compression and drawing out.

As to the most important advantage realized by boring out the ingots as done at works which practice forging hollow, is that in this way a part of the casting is removed to which the greater part of the impurities, such as phosphor, sulphur, manganese, etc., have segregated, it needs probably no further explanation that this end is attained much more effectively by Krupp's method in boring out the solid forged *shaft*, than by the process where the *ingot* is bored out, before having them forged down, in consequence of which a much smaller percentage of the impure material is bored out.

In the case of the crucible steel employed at Krupp's Works for shafts these segregations are of much less importance than in the case of open hearth steel, which, according to a paper recently read before this society, can be qualified as high grade steel only if it contains not more than .04 of 1 per cent phosphor, sulphur and other impurities, while Krupp's crucible steel contains less than .02 of 1 per cent of phosphor, sulphur, etc.

While some works resort to the fluid compressing process in

FIG. 420. (See description on page 1157.)

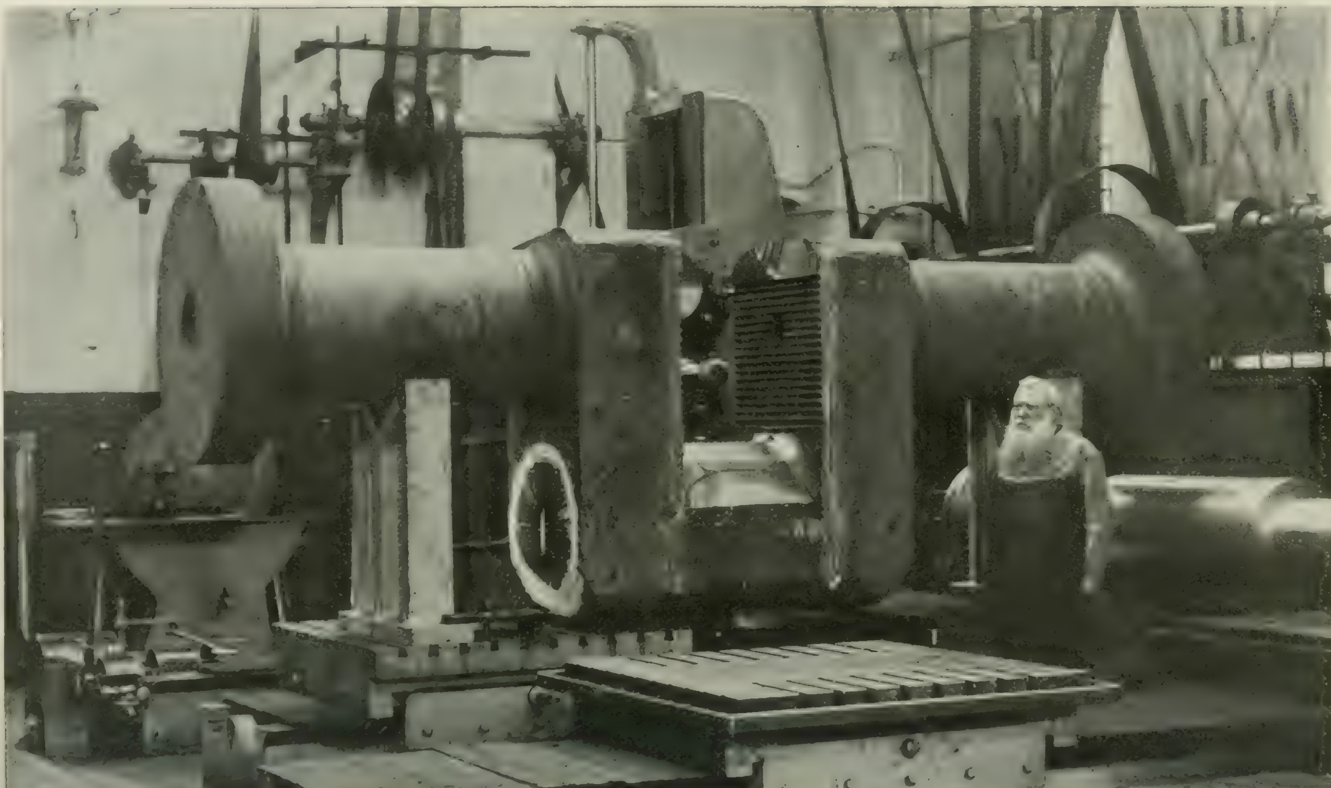


FIG. 421.—PART OF A SHAFT IN THE ROUGH MACHINED STATE.

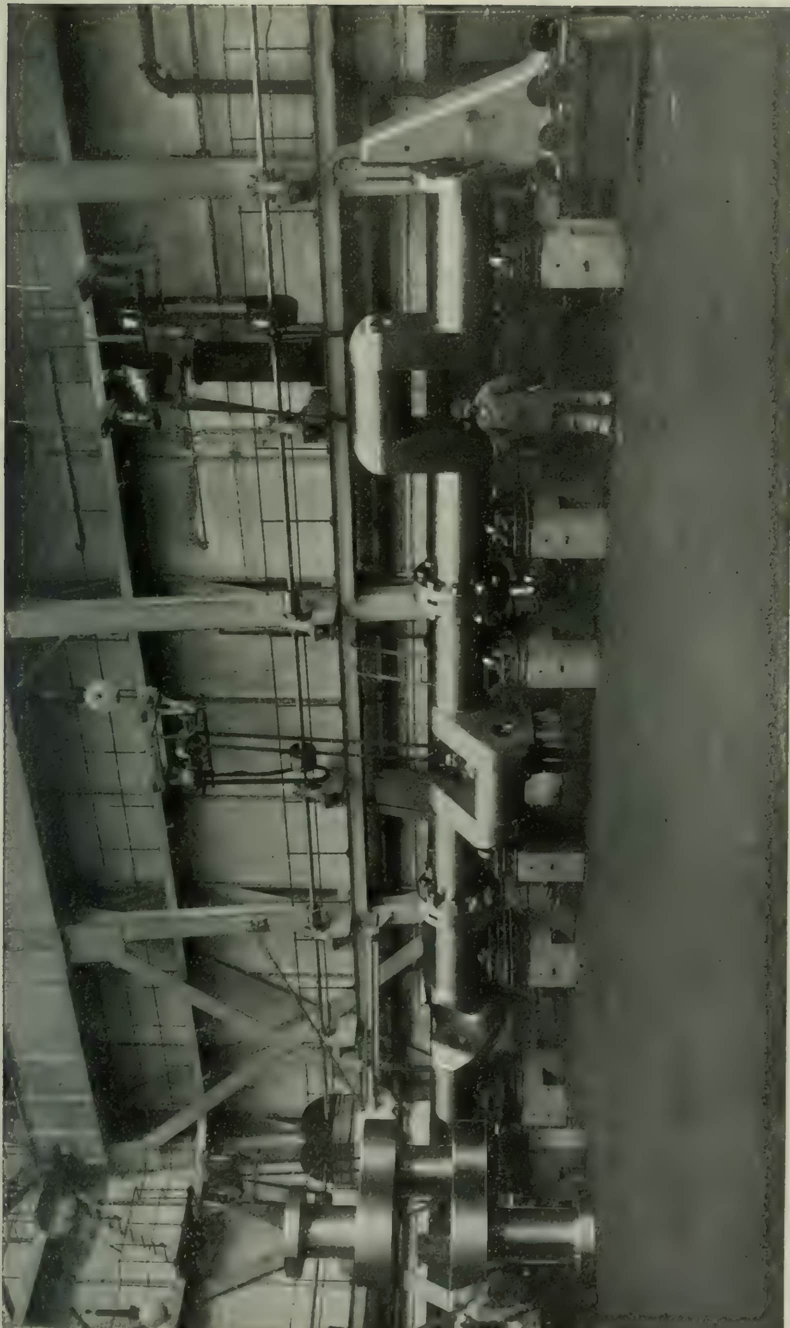


FIG. 422.—A THREE-THROW CRANK SHAFT.

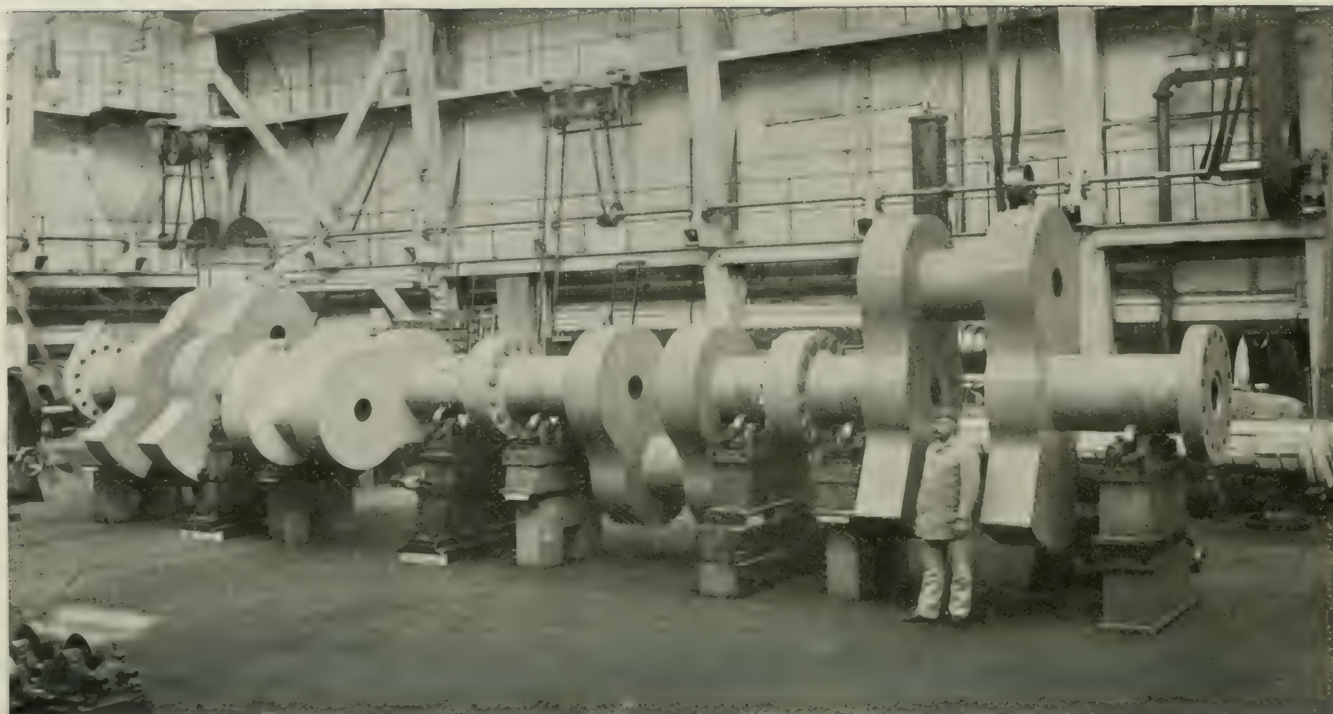


Fig. 423 A Four-Throw Crank Shaft.

order to overcome the blowholes produced by the air and gases entrained into or generated in the casting, and to minimize the detrimental effect of these blowholes, I do not intend to dispute the efficiency of this process for obtaining the results aimed at. The experience of many years, however, and of numerous investigations with ingots of the largest size, entitles Krupp to the assertion that he employs a most excellent process of his own for producing solid castings, and results of comparative experiments have pronounced in favor of the Krupp method as being much more efficient than the fluid compressing process.

In regard to the question as to which material is the best and most reliable for shafts, it should not be omitted to point out the many advantages which distinguish Krupp's crucible steel from any other kind of steel produced by any other process, for crucible steel has just those qualities which make ingots proper for such forgings as shafts. The superiority of this material is founded upon the arrangements designed especially for this purpose, and furthermore upon the practice of many years which guarantees the complete control of the process, and especially the ability of charging thousands of crucibles uniformly, filling them exclusively with puddled iron and steel, manufactured especially for this purpose, by being repeatedly refined and freed from cinder by welding, hammering and rolling and by picking out by experienced workmen. Krupp is further enabled by means of the iron mines and blast furnaces which he owns to always obtain the best raw material, and to charge every crucible exactly the same, so that at the very outset a determined hardness and quality can be expected with confidence.

The melting furnaces have been improved to such a high degree that the greatest precision in the attainment of the required heat in all the furnaces, and in all crucibles necessary for one ingot is guaranteed.

A further advantage of the crucible process is the complete absence of the detrimental effect of the furnace gases, cinder, oxygen, and other gases in the molten steel, an indispensable condition for the production of solid ingots, and a condition that requires no fluid compressing to doctor up. The existing arrangements permit the casting of ingots of crucible steel up to 85 tons, which maximum has hitherto been more than sufficient for the largest shafts likely to be ordered.

Regarding the process of forging hollow upon a mandrel it may here again be pointed out that the selection of a much larger ingot at Krupp's Works, which allows a forging down of the cross-section of the ingot from 9 to 1, surpasses completely the advantages, if there be any, of hollow forging, especially so if the forgings are bored out after having been forged under the presses than if, as is done at some works, the ingots are only drawn out from 4 to 1.

Never having seen the report of a test piece taken from the in-

side wall of a shaft that has been forged hollow on a mandrel, I cannot say that it is not as dense as the inside wall of a shaft that has been cast solid, forged and then bored. But theoretically I cannot see why it should be, as the mandrel does not act as an anvil or die, since the shaft being forged, is not suspended upon the mandrel, but rests upon the press die, from which point the resistance is offered to the forging pressure applied.

If the metal in the centre of a *solid ingot* is not compressed by hydraulic forging, the mandrel in a *hollow* ingot would be only a useless substitute for the core removed. If the centre or core of a solid ingot *is* compressed by the forging press, it is decidedly a better method to forge to the centre the greater volume of impurities and afterward remove them by boring, as per the Krupp method, than to remove only a portion of them and forge the rest into the shaft, as *must* be the case if the mandrel is at all effective.

The origin of the hollow shaft is supposed to have been at the Krupp Works and no other maker has made as many nor any that have given greater universal satisfaction, but he does not deviate from the principle of casting solid, then forging and next boring.

Furthermore, the oil tempering and annealing to which, of course, at Krupp's Works nearly every shaft as well as nearly every forging is subjected after having been bored out, outweighs and even surpasses to a much higher degree the advantages claimed of greater density and finer grain from forging hollow, and the arrangements for oil tempering and annealing forgings of the largest dimensions can be considered as a standard, and the practice in the treatment of the different qualities is assisted very efficiently by the most improved apparatus for measuring the temperatures

The certainty in the control of the crucible process guarantees the production of a material of higher tensile strength, without diminishing the ductility and toughness. There have been supplied for use in the United States a great number of shafts of the largest dimensions, the elastic limit of which was specified to be 45,000 lbs. per square inch, with an elongation of 18 per cent in 10 inches, and in all cases these minimums required for elasticity and elongation were considerably exceeded.

It may be here mentioned that at Krupp's Works nickel steel is used on a large scale for the production of shafts for steamers, also for axles and crank axles for locomotives, etc. A short time ago the Krupp's Works turned out some nickel steel shafts for the large, fast steamers, which have been built for the North German Lloyd line. The ingots, from which these shafts were forged, had a diameter of 72" and weighed 60 tons each, the diameter of the crank shaft is 24" and the weight of a single crank bored and finished complete (three cranks to each engine), is 14 tons, while in the forged state the weight was 28 tons, or twice the weight of the finished shaft.

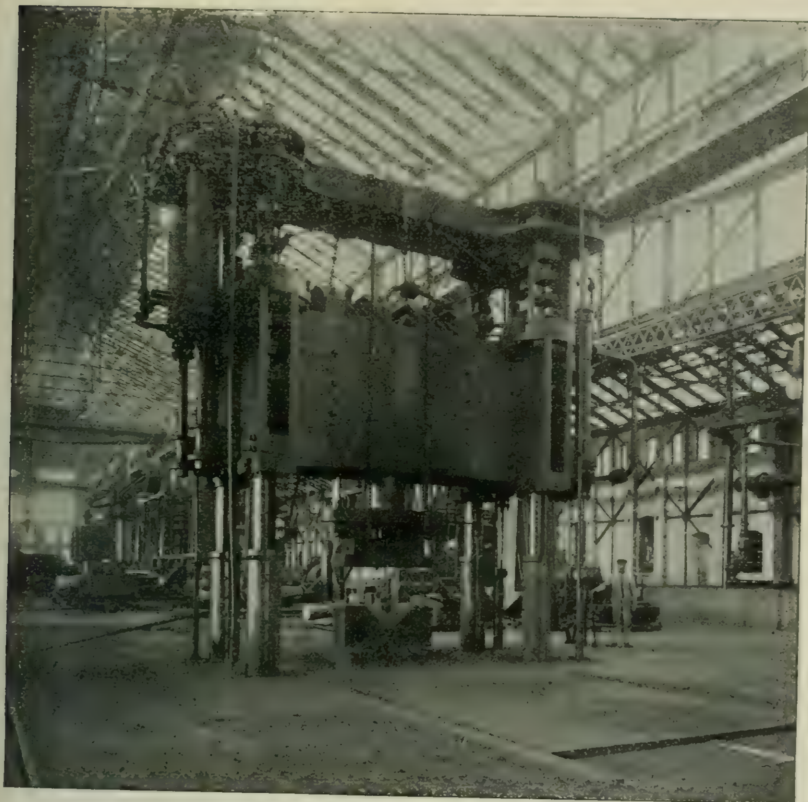


FIG. 424.—2,000-TON FORGING PRESS.

The following are the results of the physical tests of the above material made by experts of the company:

Tensile strength............	85,000 lbs. per square inch,
Elastic limit...............	60,000 " " " "
Elongation..................	20 per cent in 8 inches.
Contraction.................	55 to 60 per cent and more.

Total length, 42½ feet.

"Several extremely large hollow bored, oil tempered, crucible steel shafts have been furnished by the Krupp Works for service in the United States from which test bars 2″ in diameter, 48″ long, tested at the Watertown Arsenal by the United States Government inspectors showed an ultimate tensile strength of 97,780 lbs., and an elastic limit of 64,000 lbs. per sq. inch, and a reduction of area at point of fracture of 51% and elongation in 48 inches of 6.67 inches."

The usual quality of open hearth and crucible steel furnished

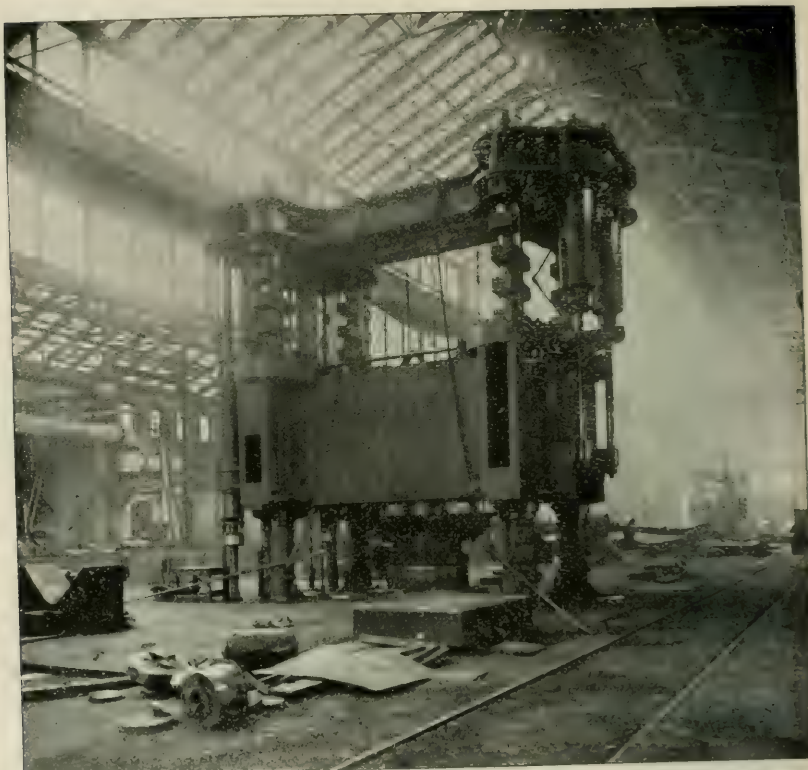


FIG. 425.—5,000-TON FORGING PRESS.

by the Krupp Works for crank pins, piston rods, connecting rods, etc., when no specifications are furnished will test about as follows:

Crucible Steel—Tensile strength, 78,000 lbs., per square inch; elastic limit, 50,000 lbs. per square inch; elongation, 22.6%; measured on 8″ length.

Open Hearth Steel—Tensile strength, 72,000 lbs. per square inch; elastic limit, 42,000 lbs. per square inch; elongation, 22%; measured on 8″ length.

A 1″ square section of either piece will bend double, cold, without showing fracture.

I therefore believe that we find Krupp's material, arrangements, and methods outweigh all the advantages which some works claim to have realized by their method of forging hollow, and guarantees these advantages at least in the same, if not in a much higher degree. This is established by the favorable experience with Krupp's shafts in service during a great number of years, and the

tact that a great number of shafts of Krupp's material have taken the place of broken shafts of other makes, some of which were fluid compressed steel.

In regard to Krupp's open hearth steel, it may be stated that Krupp has the best material at his disposal in the shape of scrap and turnings resulting from the extensive production of crucible steel, and it can be asserted in this respect that Krupp's open hearth steel is not surpassed by any other steel made by the same process, but that on the contrary, this steel can be stated to be of the best quality, and there exists scarcely any other manufacturer who has at his disposal such an excellent and pure scrap material.

At Krupp's Works there are altogether 21 open hearth furnaces, partly for the basic process and partly for the acid process, varying in size from 10 to 40 tons capacity, and with a total capacity of 300 tons. The largest ingots likely to be demanded can, therefore, be cast.

DESCRIPTION OF ILLUSTRATIONS.

Fig. 420—In front, one of the open hearth steel thrust shafts for Steamship Havel and Steamship Spree; weight, 32,320 lbs.; dimensions, 18 feet 2½″ long; diameters, 22$\frac{4}{10}$″ and 41¾″.

Behind, two parts of a three throw crank shaft of nickel steel for the North German Lloyd's Steamer Kaiser Fredrich III; weight of each part, 29,982 lbs.

On the left hand side, forging of 1/3 of the same crank shaft of nickel steel; weight, 65,830 lbs.

On the right hand side, 1/3 of the same shaft on the lathe.

Fig. 421—Part of the nickel steel shaft for Steamer Kaiser Fredrich III, in the rough machined state; weight, 33,069 lbs.

Fig. 422—Finished three throw crank shaft of nickel steel for Steamship Fredrich III; weight, 88,920 lbs.; length, 42 feet 5⅞″; diameter, 23-6/10″; tensile strength, 88,000 lbs. per square inch; elastic limit, 60,000 lbs. per square inch; elongation, 20, 5% measured on 8″

On the left part of a nickel steel crank shaft for Steamship Kaiser Wilhelm; weight, 39,860 lbs.

Fig. 423—Finished, built up four throw crank shaft of nickel steel for Steamship Kaiser Wilhelm der Grosse (North German Lloyd); weight, 183,640 lbs.; length, 45 feet 9½″; diameter, 23⅝″; tensile strength, 85,000 lbs. per square inch; elastic limit, 58,000 per square inch; elongation, 20%; measured on 8″.

Fig. 424—2,000 tons forging press.

Fig. 425—5,000 tons forging press.

Fig. 426—View of Krump's works at Essen, Germany.

FIG. 426. VIEW OF KRUPP'S WORKS AT ESSEN, GERMANY.

WRITTEN DISCUSSION.

Mr. H. F. J. Porter.

This paper, as it is presented, is somewhat contradictory in its purport. It begins by saying that it is not the writer's "intention to deal in detail with the many processes of manufacturing hollow bored shafts and steel forgings, as the various methods have previously been extensively presented and discussed." After this, the whole paper is devoted to criticising the details of these very processes. This criticism is based on what seems to be such evident misunderstanding of the principles involved in the working of these processes, that I deem it only right to correct it for reference in the records of the Society.

The writer also says that it is his "intention to show why the Krupp Works, after having experimented with the different processes, adhere to their present method." I have failed to find the promised explanation, however, and therefore I presume that it is covered solely by the assertion that "Krupp's material, arrangements and methods outweigh all the advantages claimed by others, this being established by the favorable experience with his shafts in service during a great number of years, and the fact that a great number of shafts of his material have taken the place of broken shafts of other makes." As there are, however, plenty of other manufacturers who can make such an assertion as the above, it means very little. Probably as many of Krupp's forgings have been replaced by those of other makes, as the reverse. There are other manufacturers, beside Krupp, who own their own mines, blast furnaces, etc., and there is no reason why, if it can be shown that their methods of manufacture are equally good, their product should not be equal to that of Krupp.

I am not a little surprised, however, to see in this paper an attempt made to defend old practice, especially in the face of the fact that it is rapidly being superseded by more modern methods, even by Krupp himself. The latter has not been an originator, but has, from time to time, adopted the methods of others as improved processes have been brought out. In fact, he has followed English practice most consistently, as may be seen from the following figures, those referring to Krupp being taken from a pamphlet, entitled "Fried. Krupp. Statistical Data," furnished to me by Thos. Prosser & Son of New York City.

Crucible steel was invented by Daniel Huntsman in England in 1741; its manufacture was subsequently taken up in 1811 by Krupp. Nasmyth invented the steam hammer in England in 1842, and its use was common there and in France before it was taken up by Krupp. His fifty-ton hammer, so well-known the world over, was built in 1861. The Bessemer process, invented in England in 1856, was introduced at Krupp's in 1864. Open-hearth steel, in common use in England in 1867, was introduced at Krupp's in 1889 and 1890. Hydraulic forging presses, in use at

Whitworth's in England in 1856, and in the United States in 1888, were taken up by Krupp only in 1890 to 1892. Hollow shafts were made in England long before Krupp took up their manufacture.

Yet, although Krupp has shown himself to be very slow in adopting improvements projected by others, it must be acknowledged that when he does take them up, the skill with which he handles their details commands the admiration of the world.

Crucible steel, when properly made, is of high grade; but owing to the large number of crucibles—thousands sometimes, according to this paper—in which the metal composing a single ingot is melted, the product is not always uniform. The pouring of the contents of these crucibles into the ladle or mould is attendant with the oxidation of the metal, which is by no means beneficial. The handling of so many crucibles also requires the greatest skill and care. In overcoming these difficulties much expense is entailed, and as equally good forgings can be obtained from the "open-hearth" product by modern appliances, and at much lower cost, the latter is rapidly replacing it, even at Krupp's own works.

There has never been any question regarding the excellence of Krupp's highest grade of crucible steel—the only grade mentioned in the paper. The writer, however, compares the quality of Krupp's oil-tempered crucible steel with open-hearth steel hollow forged. These grades are not by any means comparable. Krupp's crucible steel oil-tempered, or his nickel steel oil-tempered, can be compared to open-hearth nickel steel fluid-compressed and oil-tempered made by other manufacturers. These are of the same quality, have the same physical properties, and the latter is much the cheaper. Krupp's open-hearth steel can be compared with the open-hearth steel made by others, both as to grade and price.

There is nothing very remarkable in the physical properties shown in the tests referred to in the paper. They probably were not taken from prolongations taken from the forgings themselves, however. No manufacturer would forge a prolongation forty-eight inches long on the end of a shaft to take a test from, when he could get it from a bar two inches long at a small fraction of the expense. Tests equal to those mentioned and taken from forged prolongations of forgings have to be met daily by manufacturers in this country, to meet U. S. Government specifications and those of representative engineers. The U. S. Government requires steel for forgings to contain not more than .04 of one per cent phosphorus and sulphur, and steel which will show such excellent results as were brought out prominently by the performance of the engines and guns of the U. S. S. "Oregon" and other vessels of the Navy during the recent unpleasantness with Spain, must be acknowledged even by the most prejudiced to be high grade. In these days of enterprise and progress, however, grade is simply a matter of price.

There was a time, years ago, when steel-making was a trade with which it was considered undignified for people with brains to be connected, and when smelters, rollers and forgemen were paid high prices for the skill and secrets of manufacture which they were supposed to possess Nowadays, however, education through the medium of scientific institutions, the technical press, engineering societies, etc., by disseminating metallurgical knowledge, has raised steel-making to an art to which the greatest minds of the times have devoted their best energies. If the Chinese government should to-morrow decide to erect in the center of their dominion a steel works capable of turning out the very finest product, it would only be a question of money and a short time before steel forgings could be turned out there the equal of those produced anywhere in the world.

I note an unfortunate use of words in the following expression near the bottom of page 1153--"A further advantage of the crucble process is * * a condition that requires no fluid compression to doctor up.' In the face of this remark, what is intended by the assertion at the head of the same page, "The experience of many years, however, and of numerous investigations with ingots of the largest size, entitles Krupp to the assertion that he employs a most excellent process of his own for producing solid castings, and results of comparative experiments have pronounced in favor of the Krupp method as being much more efficient than the fluid compression process." More efficient in what? Doctoring up? As there seems to be a desire on the part of the writer to relegate the Krupp method to the realm of mystery, it cannot be discussed here intelligently. I wish, however, as both the fluid compression process and Krupp's secret process are comprehended under the same category, to say that there are two ways of doctoring up; one by prevention, an ounce of which the old saw has it is better than a pound of the other, viz., cure. Under the first of these ways comes fluid compression, with 7,000 tons of tendency towards prevention Whether Krupp's secret method comes under this or not, no effort is made in this paper to inform us.

From the second paragraph on page 1154, however, where the writer says, "It is a decidedly better method to forge to the center the greater volume of impurities and afterwards remove them by boring, as per the Krupp method," it would seem that the method referred to does not tend to *prevent* segregation, and it is extremely doubtful whether any method, secret or otherwise, can cure it subsequent to the forging, which immediately follows.

There are, however, no mysteries nowadays in steel manufacture, and the fluid compression process is universally conceded to be very efficient and the best known for producing solid and homogeneous steel.

Taking up for consideration that part of the paper which is devoted to the criticism of various processes which the writer says

are not in use at Krupp's works: In the first place, reference to the "fluid-compression" process is so evidently based on an inadequate idea of its working that a mere reference to actual conditions will set it straight. All properly equipped fluid-compression plants have their moulds so constructed that air and gases can escape at vents located along their sides, even near the bottom. The type of fluid-compression plant where the air and gas cells were forced to the upper part of the mould was the first made and was improved upon as described years ago. If Krupp has confined his experiments to *that* type of machine, it is not to be wondered at that he has failed to make it work satisfactorily. Fluid-compression does not *entirely* prevent segregation, but it does *retard* it, and a fluid-compressed steel ingot, bored for hollow forging, *has no segregation.* All solid ingots segregate to their center, whether fluid-compressed or not; the amount of this defect being proportionate to the diameter of the ingot, so that ingots three times the diameter of the finished forgings which this paper says is the rule at the Krupp Works would, other conditions being the same, have an exceptional amount of segregation to be taken care of.

I am afraid that the writer has been misinformed regarding the size of ingots used by Krupp. The excessive amount of segregation, together with the grave disadvantage of handling unnecessarily large masses of steel, would not be compensated for by the additional amount of work put into the metal by the forging process. A crank shaft, Fig. 421, however, is shown as evidence of this rule, viz., twenty-four inches diameter from a seventy-two inch ingot. The crank web in this shaft is the part which determined the size of the ingot, and in reality the ingot mentioned is one of unusual shape from which such a forging would be made, viz., seventy-two inches diameter by one hundred and ten inches long.

Recently shafts were forged in this country, thirty-seven inches in diameter with a sixteen-inch hole through them. These required a 5,000 ton press to work them down from the hollow ingot. Had they been made from a solid ingot, a much heavier press would have been required to forge them. If a solid ingot had been used three times the diameter of the finished shaft, or one hundred and eleven inches in diameter, a 15,000 ton press would have been needed. Such a press Krupp does not possess. What does he do when confronted with such conditions?

With reference to the critical comparison of hollow forging and solid forging and boring,—the fact that there is absolutely no segregation left in a hollow ingot to be subsequently forged into a hollow shaft, leaves it very doubtful to my mind whether Krupp's method of forging the segregation into the center and then boring it out can be considered as sure a method of getting rid of the segregation, particularly where the amount of segregation is as great as it would be in an ingot three times the diameter

of the finished forging. I cannot see that the act of forging a solid shaft would drive the segregation to the center, as the latter is already occupied by other metal. I should suppose, rather, that the segregation would be pretty well disseminated throughout the shaft. Tests show that this is, in fact, what takes place, and has led to the more modern process of hollow forging on a mandrel.

Had the writer seen tests of bars taken from the side wall of a shaft which has been forged hollow on a mandrel, he would not have been led into the error of supposing that the cold hard core presented by the mandrel would have a different effect from the hot (and therefore soft) core presented by the center of a solid ingot.

I give some tests herewith, so that he will not fall into a similar error again:

PROPELLER SHAFT OF U. S. S. "IOWA".

	Tensile Strength.	Elastic Limit.	Elongation.	Contraction.
Outside Bar No. 1	96,770	60,090	23.85%	54.56%
Outside Bar No. 2	98,800	61,110	22.50%	56.44%
Inside Bar No. 1	97,270	61,110	24.55%	57.74%
Inside Bar No. 2	97,150	60,130	23.85%	54.10%

The writer is totally at variance with theory and experience when he says that keeping ingots hot prevents "piping." This defect is produced in the ingot during the process of solidification of the molten metal; and inasmuch as an ingot cannot be removed from its mould until it is solid, all piping that is going to form has been formed before it is subjected to the process of continued heating to which Krupp's ingots are subjected. Krupp, however, is not the only manufacturer who keeps his ingots hot until used. Wherever practicable, other manufacturers adopt the same practice. The dangers attending the re-heating of *solid* ingots do not, however, apply to *hollow* ingots, as already explained in my previous paper on "STEEL FORGINGS," so that the criticism on this subject is invalid.

Both Krupp and other manufacturers are working with the same ends in view, viz., first, to improve the quality of their output by whatever methods are best suited for their purpose, and second, to reduce the cost to the consumer. Each manufacturer pursues these objects in his own way and as a result of the enterprise and intelligence which has been expended on the art, as excellent forgings can be procured today in this country, in England and in France, as can be obtained from Krupp in Germany.

CLOSURE.

By Geo. H. Bryant, Asso. Mem. W. S. E.

Replying to Mr. Porter's criticism, will say that my statement, "that Krupp's material arrangements and methods outweigh all advantages claimed by others," etc., I believe to be pertinent in discussing this subject, for the Krupp Works owning or controlling about six hundred ore mines in addition to their own coal mines and blast furnaces in the various countries of Europe, every stage of manufacture is under their own supervision, and they are not dependent on the open market for a miscellaneous assortment of crude material, and their different grades of steel can, therefore, always be relied upon to be of the same uniform quality. If there are "plenty of other manufacturers who can make such an assertion" I have never heard of them, and I fear Mr. Porter is making a very broad statement. It is a well-known fact, of course, that certain ores are fitted only for certain grades of steel, consequently the great number of mines that are owned by the Krupp Works, and, therefore, the great variety of ores, enable them to select such ore as is fit for the steel to be produced and to make very careful selections from this particular grade of ore. The "old practice" I am defending is, indeed, an old practice of making steel. However, the Krupp Works are the only works today that have carried it to perfection, and the only works that can cast an ingot from an unlimited number of crucibles and produce an homogeneous steel. The largest ingot that has ever been cast by any other works that I know of was cast in England from 95 crucibles of 45 pounds each. I am careful to state a homogeneous steel, for it is well known that experiments have been going on in a very large number of the steel plants of the United States in the casting of large crucible steel ingots for a number of years, and none have been successful in making a homogeneous steel, as has been proven by the product that has been produced and used. In fact, the Krupp Works are the only works in existence that can pour from an unlimited number of crucibles, as stated in my paper, and produce a uniform steel. While Krupp is not the inventor of crucible steel, he does not assert that he is; ever since its invention he has, however, always been able to cast a larger block of steel than any other steel maker and produce a homogeneous metal, as is shown by the following list of exhibits of crucible cast-steel blocks, with the various dates of the expositions where he has always taken the highest awards.

1851 in London a block weighing 2¼ tons.
1855 in Paris a block weighing 10 tons.
1862 in London a block weighing 20 tons.
1867 in Paris a block weighing 40 tons.
1873 in Vienna a block weighing 52½ tons.

The last block, exhibited in Vienna weighing 52½ tons, was made from 1,800 crucibles, each containing about sixty pounds. It was worked under a fifty pound hammer to show the malleability of the material, and cuts were made in four different places while in a red hot state to show when broken off later the soundness and density of the casting. Since this casting, made in 1873, Mr. Krupp has cast many crucible steel blocks much larger and always obtained homogeneous steel from them. As Mr. Porter states, the pouring of this large number of crucibles is indeed a skillful process and a process which Mr. Krupp has guarded carefully for a number of years. The Krupp Crucible Steel is always uniform and homogeneous, regardless of the number of crucibles cast, even though he does not claim to have originated, as might be supposed from Mr. Porter's criticism, every form of steel or machinery invented. Krupp, however, originated the hollow bored shaft, though I erred in stating that I supposed it to have been at the Krupp Works. I will say now, however, that the first hollow bored shaft was a Krupp shaft bored under the direction of a Krupp engineer to remove a slight check that was developing in the center of a solid shaft. The shaft was placed again in service with entirely satisfactory results. Whether this work was done at the Krupp Works in Essen or elsewhere, I cannot state definitely, or whether Mr. Krupp immediately thereafter took up the manufacture of hollow bored shafts; but it establishes the fact that he did originate the hollow forgings. In controverting Mr. Porter's further positive statement, that Mr. Krupp has not been an originator, I beg to call his attention to probably one of the most successful inventions in the steel industry, that of manufacturing Weldless Steel Tires, patent for which was granted Krupp in 1853; a style of tires that was first introduced by him in the United States, and from which time has maintained the highest grade of perfection, as a large number of consumers in the United States and elsewhere can testify. The tests submitted in my paper I believe to be "remarkabie," only because they represent the usual grades of steel furnished by the Krupp Works. Whether they were all taken from prolongations, I am unable to state, but presume they were, as it is the usual custom at the Krupp Works. They do not advocate the testing of pieces of less than eight inches, as the percentage of elongation is too great in a two inch piece to be at all accurate. The difference in the elongation in a two inch and an eight inch piece being in wrought iron about thirty per cent, and in forged steel about ten per cent greater than in wrought iron, the difference being in favor of the two inch test piece.

Referring to his criticism as to segregation, will say that I think he is mistaken, as segregation in an ingot does not increase in proportion to the increase of the diameter of ingot. But it is a well-known fact that in large ingots segregation is more observable and pronounced in the center than in a small ingot; this

should not be construed, however, to mean that it increases in area throughout the ingot in proportion as the diameter increases. Segregation takes place in the last part of the ingot to cool, and in a large ingot containing a proportionate quantity of the materials causing segregation, it must necessarily be more pronounced in the heart of the ingot, but it will not increase in area in proportion as the diameter of the ingot increases, though it may increase in quantity in proportion as the total weight of the ingot is increased.

The writer has not been "misinformed regarding the size of ingots used by Krupp," and it will, therefore, be seen that in drawing out in the ratio of 9 to 1 that the amount of segregation forged to the center of the ingot and there drawn out in being forged down, is not the serious problem that the criticism might lead one to believe; nor is the danger from piping as serious as in an ingot that is forged down from 4 to 1, owing to the fact that it is being worked before it has cooled in its center. Mr. Porter is entirely wrong when he states that an ingot cannot be removed from the mould until it is solid; and that as piping is formed while the ingot is solidifying, which we of course know is entirely true, that the Krupp processes will not tend to prevent piping. It is well known that the interior of an ingot remains in a liquid state long after its outside has solidified sufficiently to be removed from the mould, and Mr. Porter doubtless knows there are many methods used to partially solidify the ends of an ingot so that it may be removed from the mould while the center or heart of the ingot is still in the fluid state, and placed in a hydraulic press where it can be held in compressive stress graduated in accordance with its temperature with an ever-increasing pressure that will to a great extent prevent piping taking place, and an ingot may be forged down and drawn out with but the slightest appearance of piping in its heart, which is afterward removed by boring.

In reference to forcing all gathering air or gas cells higher in the mould, I, of course, knew before making this statement of the arrangement of vents in the mould; but even with these vents I still believe that the general movement of gas in steel under pressure is toward the top of the mould, and I do not intend to convey the idea that this was the sole action of the gas.

Dimensions of the crank shaft for the North German Lloyd Steamship, shown in Fig. 423, and referred to in Mr. Porter's letter as probably incorrect, are correct both in the ingot dimensions as well as in the finished shaft dimensions. The flange on the end is the only portion that has not been forged down from three diameters to one, but which has been forged down to the usual dimensions of other makers, of two to one, though every other part of the shaft has been forged from three diameters to one, as stated is the universal custom at the Krupp Works

The tests submitted by Mr. Porter from the propeller shaft of

the United States Steamship Iowa, shows the usual benefit derived from forging any piece of steel, but I do not see it proves the benefit derived from the use of the mandrel. Mr. Porter errs in stating that Krupp is rapidly replacing his crucible method with the open hearth process because of the great carefulness and expense involved in making crucible steel; for this is not a fact, as Mr. Krupp is increasing his crucible output rather than decreasing and is making today a finer grade of crucible steel than he has ever manufactured before. He is undoubtedly making a higher grade of open hearth steel, but his open hearth process is not replacing or substituting his crucible process, as a visit to his Works will very quickly show.

NOTES.

Paints for the Preservation of Wood and Metal Structures.

As the subject of paints for the preservation of wood and metal structures has received a great deal of attention from members of our society, I venture to send the Society a signboard for the information of such members as have the opportunity of seeing it and who are interested in the subject.

This board was erected on our station at Harper's Ferry in 1872. It was taken down in 1896. In the Fall of 1897 I found it lying with the letter side up on a scrap pile at Dubuque and it has been under cover since then. It was located on the south side of the depot above the office door, and as the building is two stories high, the projection of the roof did not afford it any protection. The depot is located on the river bank with high bluffs near by on the west side, and nothing to interfere with the east winds coming from across the river. I judge that the original paint was white lead and that the letters were painted with lampblack, the shading being of some darker color than white, probably a mixture of lampblack and white lead.

It has never been painted since the sign was first erected. I wish to call your attention to the preservative power of the black paint. It will be noticed that the letters stand in relief on the board, the wood being worn away where it is protected only by the white paint. The shading of the letters also stand out in relief, but not so prominently as the body of the letters which were painted black. Where there were knots in the board, these seem to have been smoothed over with putty, which stood very well. It appears to me that the weather has cut under the letters more from the eastern exposure than from the western, which is natural enough, as the western exposure was protected by the bluff which I have mentioned. I have always been a believer in lampblack paint as the purest of carbon paint, and consider this sign an object lesson in support of that belief.

ONWARD BATES.
(Engr. and Supt. Bridges and Buildings, C., M. & St. P. Ry.)

AUTHOR'S CLOSURE

Of discussion on paper read before the Society, June 1st, 1898. Measuring Apparatus, Kings County (N. Y.) Survey, by Samuel McElroy, Mem. W. S. E.

1. When I was engaged as Assistant City Surveyor at Albany, N. Y., in 1847, we used carefully made and tested linen tapes which were accurate for ordinary city work. Tests were made with pine rods.

July 10th and August 7th, 1860, Wm. H. Paine, C. E., of Sheboygan, invented and began to introduce his 100-foot steel tape, which was at once adopted by me and other Eastern engineers and surveyors. With it we also had the "Chesterman" 50-foot

steel tapes, which we found very valuable for ordinary work. These were used for blocking out and filling in the town survey work.

2. The only reliable mode of transferring stations for base lines is that of *face contact*, unless tedious care is used; rods readily act.

3. Steel wires, tapes or ribands are liable to have different tension and temperature resistances in the same length; and it is a difficult operation to determine the varied or the mean temperatures under sunshine, driving clouds or varying winds at different hours; air thermometers do not fully give these structural changes.

4. For such particular work as our long elevated railways and other assemblages of structural iron, 25-foot pine rods are used with us. As to their reliability and convenience, the Kings County tests are conclusive.

5. On the small stretched wire we had, or suspended, the ordinary steel tape could not have been used without most tedious and unsatisfactory marking and transfer of the stations.

SAMUEL MCELROY.

ABSTRACTS OF PAPERS IN FOREIGN AND AMERICAN TRANSACTIONS AND PERIODICALS.

THE LATE SIR HENRY BESSEMER.

(From Engineering, London, Eng., March 18, 1898.)

It is with the deepest feelings of regret that we write the word "late" before the name of Sir Henry Bessemer. To within a week or so of his death he retained the intellectual activity which was the prominent characteristic of his personality, and one could not realize that he carried the weight of 85 years. Although by no means a man of robust health, the burden of age lay but lightly on his bodily frame, while his mind disdained to regard as a trouble any part of the task of carrying it. Full of schemes and plans, ever experimenting and designing, each day was filled with interest, and he had not time to feel old. In listening to his projects one could imagine oneself in the company of a man barely entering manhood, while when the conversation turned to what he had accomplished, it seemed as if he must have had the gift of living three concurrent lives; it appeared impossible that so much could have been crowded into one existence.

If we had to express in one word the salient features of the engineering world for the last 40 years, we should certainly write "Bessemer." That word is more apt for the purpose and more full of meaning than any other which could be found. The majority of our readers cannot go back in memory to the time when there was no Bessemer steel, and so they may not have realized how great was the change effected by its introduction. We may remind them that previous to 1858 all steel was made by the cementation process, and that in that year the total output of Sheffield was under 50,000 tons. Practically this was all used for cutlery, tools, springs, and the like, and iron was the sole material for rails and structural work.

Now let us compare this with 1896, the last year for which we have complete figures, and note how immense is the change. In that year the production of Bessemer steel ingots in Great Britain amounted to 1,815,842 tons, while in the United States it reached 3,019,906 tons. When we carry our thoughts back from the metal to the inventor, we get some faint idea of how much the world owes to his genius, and to the pertinacity with which he stuck to his ideas in the face of opposition and ridicule. How strenuous—and in many respects how bitter—this opposition was, is recorded in the earlier volumes of this journal, and we have the keenest remembrance of how, through it all, Bessemer retained his unwavering faith in the future of the material he had created.

We leave our readers to trace his influence for themselves in the particular fields in which they are engaged, setting themselves in imagination to reconstruct in iron the thousand and one objects they now make in steel. Possibly, however, some of them have so little knowledge of the limitations of puddled iron, that they cannot even approach the problem.

Bessemer's name has spread beyond the limits of the profession in a way that is almost unknown among engineers. You might stop the first man in the street, and find that he had heard of Bessemer steel. You might even repeat the experiment in most European cities with a very fair chance of success, while in America some seven towns and cities have honored themselves by adopting his name. Nearly one-third of the vast output of Bessemer steel has gone into rails, besides immense quantities into axles and tyres, not only greatly cheapening the working of railways, and so reducing the cost of transport of everything we consume, but rendering it practicable to deal with a concentration of heavy traffic with which it would simply have been impossible to cope under the old conditions. Of the destination of the remainder it is not possible to speak so definitely, but its broad effect has been to cheapen production, either directly, or by producing a better product at the old cost, or more often by enabling machine work to be substituted for hand labor. Sir Henry Bessemer reaped a large return for his invention, but his reward was a mere bagatelle compared with the actual money gain which has accrued to the general public. It is seldom that society recognizes to whom it is indebted for the amelioration of its condition, but in this instance it has not been altogether unmindful of the man who has heaped such benefits upon it.

How numerous and how varied were Bessemer's labors are matters known only to those who had the advantage of his intimate acquaintance, but those who have heard from his own lips the stories of his early life and of his never-ceasing struggles with fresh problems, will not soon forget the privilege. It is only in illustration of his character that we can refer to some of the episodes in his career. The time will come when his life will be dealt with at length; and we are glad to know that the materials for such a work are in existence. We have already referred to the well-known fact that, unlike many inventors, he reaped such a reward for his invention of steel, that he could spend the evening of his life in dealing with problems which so greatly interested him, and on which, up to the last, he brought so much inventive skill and energy to bear. We shall, however, dispel a generally-held opinion, when we add that his title was not bestowed in recognition of the work of his ripe manhood, but in tardy acknowledgement of a most important invention made voluntarily for the government in the days when the fire of youth burned brightly, and he saw visions of an immediate fortune laid at its

feet by a grateful country. The country, as represented by the Inland Revenue Department, appropriated the invention, but practically ignored the inventor, although at that time it was known that stamps were transferred from old deeds to the new ones, and that they were forged in other ways to the probable extent of £100,000 per year. One morning young Bessemer (he was then not 20 years of age) called at Somerset House with a number of stamps he had forged himself, and also with a method of impressing stamps which was practically proof against forgery. The department jumped at his idea, obtained an act to recall all unused stamps, and started afresh on a new plan. Promises were made to the inventor and not fulfilled, and after dancing attendance for a long time, he withdrew from the affair, sick with hope deferred. Years passed and probably the matter was forgotten by everybody but himself. But the spirit which enabled him to fight his way through many other difficulties, kept alive the recollection, and eventually his chance came. The emperor of the French offered him the Grand Cross of the Legion of Honor, on condition he could obtain permission from his government to wear it. This permission was refused, and in 1878, other circumstances recalling this refusal, Bessemer wrote a scathing letter to the *Times* describing all the circumstances of the service he had once rendered the state. He also set to work to find the people who had been connected with the manufacture of the dies for the stamps, and to collect other evidence. He then laid the matter before Lord Beaconsfield, and after a fitting delay, he was informed that Her Most Gracious Majesty had been pleased to signify her intention of conferring the honor of knighthood upon him. The ceremony took place on June 26, 1879, and thus after some forty-six years Sir Henry Bessemer received the reward of his juvenile efforts. It is not often that a harvest is gathered so late, probably because it is seldom a man is found with so much energy as to push his claim for the payment of debt nearly half a century old.

Probably his attempt to get justice out of the Board of Inland Revenue was the only occasion on which Bessemer was defeated. It was his characteristic to attack a problem again and again, putting his whole soul into it, and proceeding as if success was certain. Had it not been for this, most of his ventures must have been failures, for they were generally matters of extreme difficulty in which he had no previous experience to guide him. He was not an iron manufacturer when he took up the great problem of his life, neither was he a trained chemist nor a metallurgist. Still earlier, when he commenced the manufacture of bronze powder, which laid the foundation of his fortune, he was entirely without knowledge of the subject, and could hardly be called an engineer. But he believed in himself and his powers, and devoted months of steady work to his experiments at a period when he could not afford to waste time. For it must be remembered that

Bessemer did not start the world with money. His father was in comfortable circumstances, but the son had to make an income for himself as soon as he came to man's estate. He tried many things while yet little more than a boy, and in each of them he attained a fair measure of success. Among these was a means of consolidating plumbago dust into a solid block for the manufacture of pencil leads, an invention which he sold for the totally inadequate sum of £200 and which is still in regular use. Next he undertook the casting of type, introducing the use of a force pump to drive the metal into a mould, as is done to this day. Messrs. Wilson, the well-known type-founders of Edinburg, bought the invention, but owing to the opposition of their workmen, they did not at the time carry it out. Next he went into the preparation of rollers for paper embossing and printing, and the production of alloys used in the preparation of "forcers" employed in embossing cards and leather. One branch of trade led him into another, while all the time he was on the watch for some outlet for his ability that should absorb his time and enable him to drop the many small manufactures which his versatile mind had originated. He was anxious to marry, and the responsibilities of matrimony could not be undertaken on the irregular sources of income which he had hitherto alone been able to procure. Still he persevered; he found a lucrative business in reproducing "Napoleon medals" in soft metal, and then he undertook to design a type-composing machine for a Mr. James Young. This was not his own venture, and although a considerable measure of success was attained, the machine did not oust the compositor.

In all these efforts we see the nature of the man. His confidence in himself was unbounded and was justified by the results that he achieved. It is noticeable that he never followed established lines. All his work was original, for he was an inventor to the tips of his fingers, and saw everything in a new light. Mere manufacturing had no interest for him. At this time he had not yet found the necessary outlet for his talents, and, one by one, he abandoned each enterprise, selling it for what he could get, and looking afield for something more worthy of his ability and promising more reward. His chance in life came by accident. The same incident had happened to hundreds of men before, but not one had had the intuition to see where it pointed, and to follow the path at all cost. He had occasion to purchase some "bronze powder," and was struck with the difference between its cost and the value of the raw material from which he assumed it was made. He paid 7s. an ounce for it, while he judged the metal was not worth more than as many pence a pound. Here was an opening indeed for a mechanical inventor, for it was evident that the powder was prepared by slow and laborious hand process. Bessemer threw himself ardently into the matter, and produced a most ingenious device for reducing brass to grains of infinitesimal

size; but, alas! they had no lustre, and were useless as bronze powders. The disappointment was great, and for a time no better idea was struck. Eventually an examination under a microscope showed that the bronze powder of commerce was in flakes, while Bessemer's powder was in grains. This put the matter in a new light, and the subject of our memoir saw before him the chance of his life. He devoted months to the preparation of machines of a commercial size, and at length he succeeded in making bronze powder which would sell at a large profit in competition with that from Nuremburg. The road to fortune was now open, but it was still a most laborious road to travel. It was imperative that the process should be kept absolutely secret from all the world except from three relatives by marriage who undertook to work it. Drawings had to be made, parts of machines were ordered from different manufacturers, then had to be put together by the inventor and his relatives without assistance, and so on. The bronze business soon began to run automatically, and he had leisure and money to experiment in many other directions. In fact, with him leisure and experiment were almost synonymous terms; as soon as his mind was free from one subject it turned to fresh fields. To do nothing was an impossibility with him, alike in his youth, his manhood and his old age, and there was nothing he touched but he left on it the marks of his genius Of course, all his discoveries were not remunerative in a financial sense, but there were several that were, particularly one for embossing velvet. For a time he obtained 6s a yard for doing the work, and even when the price fell to 1s it yet yielded a good profit.

With a mind so active and many-sided as Bessemer's, it is difficult to trace the birth of an idea. But in scanning his history we find that he had always a singular aptitude for the production and manipulation of alloys. Possibly he inherited this from his father, who made a great reputation as a type-founder. Certainly he was ever ready to produce new alloys for any particular purpose, and he was very successful in producing them with any particular physical characteristic. It can scarcely be said, however, that it was this favorite study which led him to experiment with steel. The matter seems to have had its origin in the Crimean war, when all men of mechanical tastes were considering the improvement of cannon. Bessemer endeavored to produce an elongated projectile which should be made to revolve in its flight by the passage of powder gases and air through curved holes in its body. In this he made some progress, but only to find that the guns of the day could not stand the increased strain thus thrown upon them. He went to Paris and was encouraged by the Emperor Napoleon to persevere, with the result that he attempted to produce an improved cast iron by successive refinings. This he did, until the idea seems to have struck him that he might refine the iron until it became steel, and from this arose his great invention.

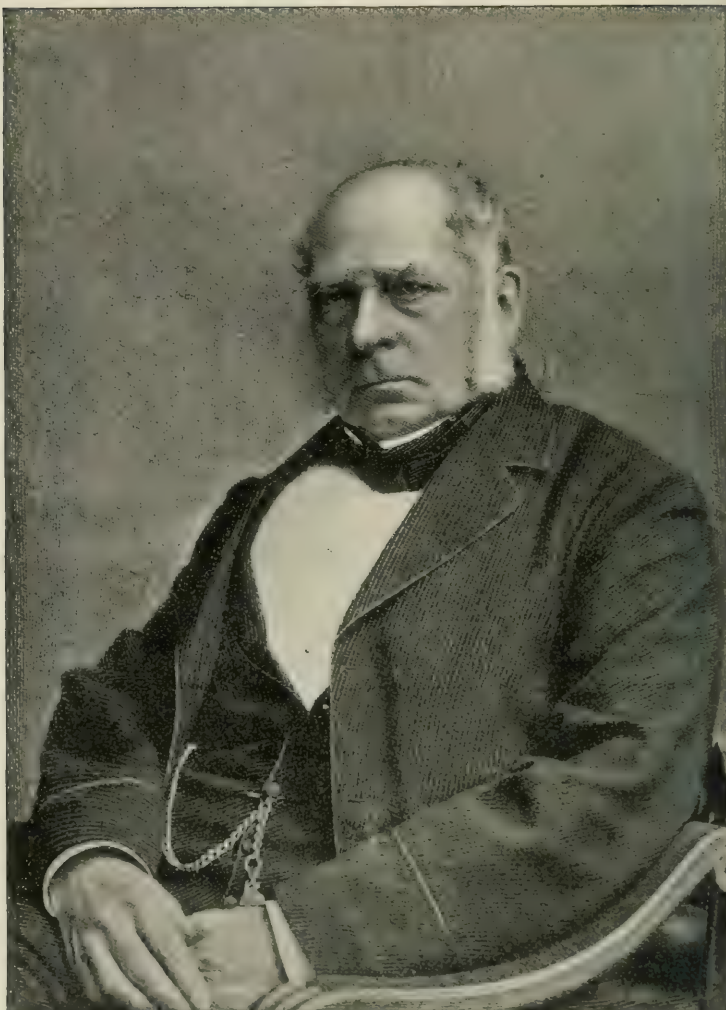
It is not our intention to re-tell the tale of Bessemer's early triumph, his immediate disappointment, and his final victory when the Sheffield manufacturers found that he was systematically underselling them by £20 a ton. All this has been related again and again, and can be found at length in our columns; it is little more than a year since we published a long account written by Sir Henry himself.* When his patents expired he was approaching 60 years of age, and was the owner of an ample fortune. He had the right to claim repose, and in a certain sense he did, for he gave up all commercial pursuits with their worries and anxieties. But as regards mechanical and scientific matters he never rested. At one time he was designing machinery for diamond polishing for the benefit of one of his grandsons; at another time he was busy on a large reflecting telescope with most complete mechanical arrangements for manipulating it; the polishing of plate glass occupied him for a while, and, indeed, one never met him but that he had some scheme in hand. It is no idle compliment to say that if a reverse of fortune had happened to him at three score and ten years of age, he could still have made a living by his inventions.

Henry Bessemer was born on January 19, 1813, at Charlton, Hertford, England, where his father had a small estate. He appears to have attended school in the neighborhood, and when his education was finished he remained at home, assisting in the type foundry, which his father then owned, and learning to be a mechanic. On March 4, 1830, his father removed to London, and he relates how keenly he felt the change from the pleasant country village, where he knew everybody, to the wilderness of bricks and mortar. In relation to this he has written "How often I thought in those early days in London, 'Shall I ever be known here? Shall I ever have the pleasure of seeing a smile of recognition light up the face of any person in these ceaseless streams of unsympathetic strangers?'" It only took 30 years to spread his name, not only over London, but over the whole metallurgical world.

Mr. Bessemer married, in 1833, Anne, the daughter of the late Mr. Richard Allen, of Amersham, and it was only last year that this happy union was severed by death. He has had two sons and one daughter, all of whom survive him.

Bessemer's memorable paper read before the British Association at Cheltenham was not published, or even alluded to, in their journal. His next paper, before the Institution of Civil Engineers, read in 1859, was awarded a Telford premium, and in 1877 he was elected a member. In 1879 he was made a Fellow of the Royal Society, in 1880 he was presented with the freedom of the city of London, in 1871–73 he was President of the Iron and Steel Institute. From abroad he received many honors. He was offered the Grand Cross of the

* See *Engineering*, vol. lxii., page 749.



Very sincerely yours
Henry Bessemer.

FROM A PHOTOGRAPH TAKEN OF HIM IN 1892, AT THE AGE OF 79 YEARS

Legion of Honor, but as permission to wear it was refused he had to be content with a large gold medal given him by Napoleon III. He was an honorary member of the Iron and Steel Board of Sweden, a freeman of the city of Hamburg, an honorary member and gold medalist of the Society of Arts and Manufactures of Berlin, and a Grand Cross of the Order of H. I. M. Francis Joseph of Austria. In contrast with this appreciation shown abroad, the action of our own government was particularly unedifying. They gave him a knighthood, when a seat in the House of Lords would have been an insufficient acknowledgment of the immense services he had rendered to the country and to humanity. It would seem as if statesmen were so immersed in party politics that their mental vision was distorted, and they are unable to discern the real sources of the prosperity of the country. Contributions to the election funds of the Liberal or Conservative parties are the surest means of gaining rank, while it is only by chance that those who, like Bessemer, found new industries and transform old ones, receive any recognition. Nevertheless, posterity will do them justice, and when 99 per cent of our politicians have been forgotten, and our titled nobodies have dropped out of recollection, the name of Bessemer will live in honor, and will shine in company with some half-dozen others who may be reckoned as the greatest benefactors of toiling humanity.

SIR HENRY BESSEMER.

(*From The Engineer, London, Eng., March 18, 1898.*)

Sir Henry Bessemer died on Tuesday evening at his residence at Denmark Hill. He was born on the 19th of January, 1813, and his long life has carried him into a generation for whom his achievements lack the interest which they possessed for the few great metallurgists, his contemporaries, yet alive. By those who had had the good fortune to know him well his death will be keenly lamented. But his increasing years and infirmities have long withdrawn him from public life, and for the younger metallurgists his name is not one with which to conjure.

Concerning the work which he accomplished, most of the details are familiar to those interested in the manufacture of steel, and nothing more is necessary—or indeed possible—just now than a recapitulation of certain prominent facts and dates. But the man himself was too remarkable in many respects, and his career too instructive and suggestive, to be passed over wholly in silence. It is satisfactory to know that for a considerable period he was at work on an autobiography. Bessemer wrote excellent English. He was extremely genial, and very happy and sanguine in his disposition, and he brought therefore excellent qualifications to the work of authorship. The history of his life and work will consequently no doubt possess exceptional inter-

est. It will be necessary, however, to read between the lines to learn what manner of man he was. Bessemer was a very peculiar product of the nineteenth century. His total lack of systematic scientific training at once made him and marred him. It is a noteworthy fact that in all ages, consciously or unconsciously, those who teach deem it certain that what they have to impart represents finality. We very seldom meet in text-books or hear from lecturers suggestions that improvements in such and such directions are possible. If Bessemer had been carefully taught metallurgy, as it was understood in the days of such men as Truran, for exanple, he would never have invented the Bessemer process. On his own showing, indeed, he rather blundered upon it than invented it; and he was carefully assured by those who were supposed to know all about steel making that ever had been known or could be known, that the process was wholly impossible. No scientific training stood in the way and stopped Bessemer from trying experiments. In a single instance he was successful, and his success worked a greater change in the world's ways than it is easy to realize. But it is said that he spent no less than £10,000 on Patent-office fees; and of the hundreds of inventions which he made, very few attained to success. The reason must be sought in Bessemer's character. His ideas singularly lacked proportion. He failed to catalogue all the conditions affecting an invention, and determining its success or its failure; and to those whose existence he did recognize he was wholly incapable of attaching a just value. For example, he invented a steady cabin for ships, which was to prevent seasickness. This cabin or saloon was hung upon gimbals, and somewhere about the middle of it was mounted a fly-wheel weighing a couple of tons, which was to revolve at 1,000 or 1,500 revolutions per minute. The gyroscopic action of the revolving mass was to keep the saloon steady. That it would operate to prevent rolling under certain conditions was admitted. Bessemer had a model saloon fitted up in his grounds at Denmark Hill, on a rocking platform, to resemble the hull of a ship. Everything worked admirably. what the inventor failed to see was that no strict parallel could be drawn between the mechanical action of the rolling platform on land and the tumultuous universality of violent motion brought about by a moderate gale in the British Channel. The Bessemer steamship, on which he certainly spent £25,000, and probably twice that sum, was a pronounced failure. Again, he spent very considerable sums on the production of a steam gun. In order that the action of the steam on the bullet might be sufficiently prolonged, the barrel was coiled up in itself in a flat spiral, terminating in a few feet of straight pipe at a tangent to the rest. He took an almost childish delight in seeing this weapon flatten lead bullets against an iron plate; he quite failed to see that there was no use for such a thing, or that it was as absolute a toy as the steam gun of Jacob Perkins. No doubt if Bessemer had had

a sound mechanical training he would have avoided this class of work; but, on the other hand, he would have lost that splendid audacity of ignorance which led him to magnificent triumphs.

Until Sir Henry Bessemer's autobiography is published very little will be generally known concerning his early life. His father was a Frenchman, an artist, and a member of the French Academy of Sciences. We believe we are correct when we state that young Bessemer first made a living by designing patterns for Paisley shawls. His sister was presented one Christmas with an illuminated gift book, in which were so-called gilt letters. She set about illuminating a book for herself, and asked her brother to get her some "gold paint." This used to be sold in "shells," and when the lad went to buy one, he found to his dismay that the shells cost half-a-crown each. Half-crowns were very scarce, but he bought a shell, and formed the idea that he would himself make gold paint. The story of his endeavor we have had the good fortune to hear from his own lips. He believed that the paint was made of Dutch metal "gold" foil, ground up to a powder with a little honey, and subsequently treated with varnish. He was on the right track, but his gold paint would not shine; it lacked lustre. At last he discovered that it was not an amorphous powder that would do. The foil must not be ground up, but torn up, until each little flake resembled the feather on a butterfly's wing. He made his machinery, and to this day the secret of its structure has, we believe, been maintained. The machine described in his patent will not work. The whole story is far too long to tell here. It must suffice to say that bronze paint was the foundation of Bessemer's fortune.

Early in his career, long before the advent of the steam gun, he turned his attention to ordnance, and tried to make shot, with spiral feathers and other devises, to do away with rifled grooves in the gun. But he could not get cast iron strong enough to satisfy his needs, and nothing would serve him but he must try to make a tougher metal. His first experiments were made in 1855. He melted pig iron in a reverberatory furnace, and into the molten metal he put broken-up bars of blister steel. He got the very high heat necessary to secure fusion by making a wide grate and giving the hearth a narrow throat. This he patented on January 10, 1855. He found the clue to this process in Fairbairn's attempt to toughen cast iron by adding some malleable scrap to the cupola, which, however, only resulted in producing white cast iron. Bessemer made a model gun of his new metal and took it over to France. He presented it to Napoleon III., who was much pleased with the weapon, and wished to reward the inventor with the Grand Cross of the Legion of Honor, which, however, the English Ambassador would not permit him to wear. He proceeded, however, to erect gun-casting works at Ruelle, for the French Government; but these were stopped by a dis-

covery which he made in London. We must here quote Bessemer's own words from a paper which he read before the American Society of Mechanical Engineers.

"On my return from the Ruelle gun foundry I resumed my experiments with the open-hearth furnace, when the remarkable incident I have twice referred to occurred in this way. Some pieces of pig iron in one side of the bath attracted my attention by remaining unmelted despite the great heat of the furnace, and I turned on a little more air through the fire-bridge with the intention of increasing the combustion; on again opening the furnace door after an interval of half an hour these two pieces of pig still remained unfused. I then took an iron bar with the intention of pushing them into the bath, when I discovered that they were merely thin shells of decarbonized iron, thus showing that atmospheric air alone was capable of wholly decarbonizing gray pig iron, and converting it into malleable iron without puddling or other manipulation. It was this which gave a new turn to my thoughts, and after due consideration I became convinced that if air could be brought into contact with a sufficiently extensive surface of molten crude iron the latter could rapidly be converted into malleable iron."

The history of the Bessemer process, even in its earliest stages, would fill a volume. The invention as it is known now was not arrived at for years. Up to a certain point Bessemer had things all his own way, and then came a crash. It was found, indeed, that steel could be made, but only with utter uncertainty as to the quality of the product. It was necessary to leave a little carbon in the metal, but the percentage depended on the duration of the blow, and no satisfactory commercial result was possible. But besides this, far from getting rid of sulphur and phosphorus, the process seemed to aggravate the evil of their presence. In a word, the whole process was a failure. He worked away for more than two years, and at last succeeded in producing a saleable article from a pure ore, but by this time the steel makers had lost all faith in the affair. Bessemer, however, about 1858 started a small steel works in Sheffield, with a partner, Robert Longsdon, Messrs. Galloway, of Manchester, supplying the plant, and steel was made and sold in small quantities.

Next, Robert Mushet appeared on the scene, and it appears to us to be beyond all doubt that to him the ultimate success on a great scale of the Bessemer process was due. To settle the carbon question he blew all the carbon out of the charge, and then added a definite quantity of speigeleisen, the manganese of which formed an invaluable ingredient. Of the disputes as to priority of invention, and the validity of Mushet's claims, we do not care to write. They are matters of history.

Mr. Bessemer and his partners were eminently successful, and realized huge profits. We have heard Sir Henry Bessemer say that he had realized himself personally one million sterling. He

went on inventing various improvements in the apparatus used for conversion; and he took out scores of patents for various other inventions, such as sugar-cane crushing machinery and telescopes. In 1875 the Bessemer Channel steamer was launched. She was designed by Mr.—now Sir—E. J. Reed, and was fully described and illustrated in our pages. She was one of the very few steamships built with four paddle wheels, two of which were forward and two aft of the swinging saloon. She was a failure from the first, slow and unhandy. On the very first trip she made she fouled Calais Pier, and did herself and the pier much harm. Her engine frames were too weak, and the great gyroscope in the saloon could not be made to work properly. The company was wound up, and we believe that the hull of the Bessemer was finally converted into a screw cattle boat, and plied in the North Sea.

To say that Sir Henry Bessemer was a genius gives but an inadequate idea of the man. The curious way in which he got at results, almost, as it were, by instinct, was very remarkable. It is nearly certain that he never really mastered the chemistry of his process, and we are strongly disposed to believe that he took far more interest in the machinery he used than he did in the details of the process it carried out. It was quite useless to tell Bessemer that any given device would not answer. He seemed to possess some special power of making things succeed which ought to have failed. Of course he committed a multitude of mistakes, but they were all swallowed up in his successes. We should but write platitudes did we attempt to dilate on the importance of the part which his process has played in the development of the carrying trade of the world. The facts are patent to everyone who pleases to give them a moment's thought.

The world began to appreciate Bessemer at a tolerable early period. He got the Telford Medal for a paper on his steel process read before the Institute of Civil Engineers in 1859. In 1871 and 1873 he was President of the Iron and Steel Institute. In 1877 he was elected a member of the Institution of Civil Engineers. In 1879 he was elected a Fellow of the Royal Society. In the same year he was knighted, and in 1880 he was presented with the Freedom of the City of London. His reputation was world-wide, and the world delighted to honor him. He married in 1833 Miss Allen, by whom he had several children. Lady Bessemer died last year.

Sir Henry Bessemer retained his health and his faculties, notwithstanding his great age, until quite recently. About three weeks ago he was taken ill and had to keep his bed, but he rallied, and wrote and talked, and no immediate danger was apprehended. On Tuesday afternoon, however, he collapsed suddenly, and passed away quietly about twenty minutes past seven.

ABSTRACT OF THE MINUTES OF THE SOCIETY.

REGULAR MEETING—6th JULY, 1898.

A regular meeting of the Society (the 386th), was held in the Society's Hall on Wednesday evening, 6th of July, 1896, Vice-President A. V. Powell in the chair.

The report of the committee, appointed at a previous meeting to prepare suitable resolutions on the death of Sir Henry Bessemer was read by the secretary, as follows:

MR. PRESIDENT The special committee appointed to take action on the death of Sir Henry Bessemer would report as follows:

The recent death of Sir Henry Bessemer has removed from the world one of the great men of the age. His greatness is peculiarly in the line of pursuits followed by the members of our engineering societies, and it seems only fitting that some notice should be taken by engineers, in their organizations as such, at this time of his life and achievements. It is too early to go into an extended biography of the man, and we are hardly familiar enough with the facts to write an obituary or eulogy.

Among others two articles have recently appeared in the English engineering periodicals on Sir Henry Bessemer, which seem to cover the main features in his life so clearly that your committee feels that they can bring the matter before the Society in no better manner at this time than to suggest that these articles be published in one issue of our journal, and the committee so recommends.

A. M. FELDMAN,
THOMAS APPLETON, } Committee.
E. GERBER,

A motion was made that the report be accepted and printed in the Journal of the Society. Carried.

Mr. Oscar Sanne was then introduced, and read his paper on "Park Bridges." Discussion followed. Mr. E. Gerber moved that a vote of thanks be extended to Mr. Sanne. Carried.

The meeting adjourned.

At a meeting of the Board of Direction, Saturday, 30th of July, 1898, Mr. John N. Reynolds was declared elected an associate, and Mr. Edward M. Hagar as an active member.

Application for active membership was received from Edward S. Cole, and referred to the membership committee.

REGULAR MEETING—3d of AUGUST, 1898.

A regular meeting (the 387th) of the Society was held in the Society's Hall on Wednesday evening, 3rd of August, 1898. In the absence of the President and Vice-President, Mr. T. W. Snow was called to the chair. A motion was made and carried that the Secretary read the papers before the meeting by title as follows: "Hollow and Solid Steel Forgings," by Mr. George H. Bryant; "Storage Reservoir for a Railroad Water Supply," by Mr. Augustus Torrey.

The meeting adjourned. NELSON L. LITTEN, Secretary.

LIBRARY NOTES.

The Library Committee wishes to express thanks for donations to the library. Back numbers of periodicals are desirable for exchanges and aid in completing valuable volumes for our files.

Since the last issue of the Journal we have received the following as gifts from the donors named:

U. S. Commission of Education—Vol. I, 1896-7.
Alfred Noble—Report State Engineer and Surveyor of N. Y., four Vols.—1863, 1894-5-6.
Institution of Mechanical Engineers, London—Proceedings, Vols. 3 and 4, July and November, 1897.
Chief Engineer, U. S. A.—Annual Report 1897, 6 Vols.
H. F. J. Porter—Fatigue of Metal in Wrought Iron Forgings.
Chas. E. Billin & Co.—Machinery and Supplies for Mines and Mills, Nos. 1 to 3.
Ingersoll-Sergeant Drill Co., Air Compressor Catalogue, Descriptive and Beautifully Illustrated, showing great variety of styles of Compressers.
Dept. Interior—U. S. Statistical Atlas of the United States—11th Census.
Dr. M. E. Wadsworth, Director Michigan Mining School, Houghton, Mich.—19 Pamphlets pertaining to Engineering, Mining and Geology.
Institution of Civil Engineers—Minutes of Proceedings, Vol. CXXXII, June, 1898.
New England Cotton Manufacturers Ass'n—Transactions of Annual Meeting, April 27-8, 1898.
U. S. Civil Service Commission—14th Report, July 1, 1896, to July 1, 1897.

The library and reading rooms are open from 9 A. M. to 5 P. M., on week days, except Saturday, until noon.

TO MEMBERS.

The Library Committee wishes suggestions as to good engineering books, new or old, that are desirable for our library. The aim is to give the greatest good to the greatest number of our members possible with the funds at our command, and the committee, composed of few members, cannot well judge wisely to meet the various needs of our membership.

Will each member please send to the Secretary of the Society the title of one or more books which he considers useful and authoritative in some line of engineering work? Please state title as fully as possible, together with the names of author and publisher, etc.

Any suggestions in regard to the library in general or in any detail will be gladly received.

ACCEPTED DESIGN FOR U. S. GOVERNMENT POST OFFICE AND CUSTOM HOUSE BUILDING AT CHICAGO.

HENRY IVES COBB, Architect

See paper by Wm. Sooy Smith, Engineer in Charge. Page 1216.

Journal of the Western Society of Engineers.

Vol. III. OCTOBER, 1898. No. 5

XLIII.

THE EQUILIBRISTAT.

By Don J. Whittemore, Mem. W. S. E.*

Read September 7, 1898.

INTRODUCTORY.

Mr. President and members of the Society of Western Engineers, before commencing my paper I wish to make a few remarks. The subject of curves on railways revives my memory of circumstances of my own experience fifty years ago on a line extending between Boston and Montreal. At that time great pains were taken in laying out curves as well as tangents, much more I think than is practiced at the present day. It was a time when the entire mileage of the country was not equaled to the mileage of the one road which I serve at the present time.

We had able men at that time, men who became noted in after life. I can mention the names of the Chesbrough brothers, John Newell, Dr. Williams, now of the Baldwin Locomotive Works, Charles Paine, Dodge and others that had to go West, for the simple reason that directors of railways in that early day were tired of the engineer, when they got their line built so that they could run a locomotive over it. The engineer was then considered an incubus,something that had caused all the expenditure they had made and brought no income, and new men were put forward; men perhaps noted as agents of 'canal boats, stage lines, or engaged in transportation generally. Some of them were appointed as superintendents and they ran the roads for eight or ten years. The result was that nearly every road in New England went into bankruptcy, and by and by they began to call the engineer back again to restore the road.

But railway building was progressing throughout the country. These men who built those railroads (and they did remarkable work too) found employment in the West, and, as you know, some of them have become honored members of this Society.

*Chief Engineer Chicago, Milwaukee & St. Paul Ry.

All sorts of notions prevailed among this class which I speak of, who operated the roads thirty-five or forty years ago, in regard to railroad building. In Ohio the superintendent of a road came to the conclusion that the theory of elevation of railway curves was all erroneous; that it was not the outer rail that should be elevated, but the inner one, and he so elevated the inner rail. Of course that did not last long.

About thirty years ago, a railway was re-organized in one of our western states, the adjoining state to this, and the New York directory thought they must have a man who was a thorough-going pusher here as a general superintendent. His record was made I believe in horsing cars in New York, but he had a considerable respect for science, and after he had been in charge a short time he heard that there were rules for the elevation of the outer rail of the railway suited to certain speeds. He called in an engineer and gave him instructions that the curves of his line should be elevated for forty miles an hour, and the outer rail was so elevated. Under his charge and at an important station was a ten degree curve in the line, at a place where all trains came either to a standstill or slowed down to a speed of six or eight miles an hour. Shortly after this curve was so elevated, a fat man was getting off the lower side of the train, his foot struck the last step, that car turned over, and the coupling of the car was strong enough to turn over every car of the train, and if newspaper accounts of this accident were correct, several passengers were killed. That is where science struck into the ground.

Happily in later days as a rule we have had able, progressive, energetic and cultured men in charge as railway managers and superintendents, with whom the engineer delights to work and from whom he receives due recognition for his meritorious efforts.

These thoughts occurred to me as probably the proper introduction to the paper I am about to read, but I want to say something in addition. Some weeks ago a man was introduced to me in my office who had at times delivered lectures on engineering subjects, and I thought he was a very proper person before whom to bring a simple little device that I had gotten up relating to railway curves, and I commenced unfortunately by saying, "Suppose you were in charge of maintenance of way of a railway and were in doubt about the curves being elevated—" "Stop, stop," he said, "I would have no doubt about that matter; I would see that they were right when the line was originally constructed."

He could not have informed me in plainer terms that he never had charge of maintenance of track, therefore I changed the subject. It struck me then that I might have more appreciative listeners among the members of this Society.

THE EQUILIBRISTAT.

It is a simple matter for the engineer of railway maintenance to give orders; but it is often difficult for him to know whether

his orders have been complied with; and even with this knowledge it is difficult to determine with the unaided eye what changes occur as time passes, through natural or other causes. As an aid to such engineer the author has devised a simple instrument, which he terms an "Equilibristat," the purpose of which is to determine the super-elevation of opposite rails of a railway track; also to determine whether the outer rail of the track on curved lines has proper super-elevation to secure a state of equilibrium to trains passing over same at a stated velocity.

I assume that all of our profession are aware of the statical laws that enter into this problem; but as this paper may be read by others not so informed, I may venture the following elementary remarks before attempting a description of the instrument that I have the honor to bring to your notice.

If a U-shaped tube be placed upright upon and transversely to the axis of a car floor, which car floor forms a parallel plane to a track that is level transversely, and if said tube be partially filled with fluid, the surface of the fluid will rise to the same level plane in the two branches or limbs of the tube; but in case one rail of the railway track upon which the car rests is higher than the opposite rail, thereby giving the floor of the car an inclination, the fluid will descend in one branch of the U-shaped tube, and in the other branch or limb will rise until the surface of the fluid in each reaches the same level plane. By observing the total change that thus takes place through the superior elevation of one rail above the other opposite, and knowing the horizontal width between the centers of the upright branches or limbs of the U-shaped tube, and also knowing the gauge of the railway track, the amount one rail is elevated above its opposite rail is readily determined.

Assuming again that this U-shaped tube partially filled with fluid is resting on a car floor and transversely to the axis of said car, and at rest on a curved line of railway track, which said track has had its outer rail elevated above its inner rail by an amount required to meet the demands of centrifugal force due to a given velocity of train, of which the car forms a part, then in this state of rest the difference in height of fluid in the two branches of the U shaped tube as measured along the branches of same, will be an index to the superior elevation of one rail of the track above its opposite rail; but when the car is moving along the curved railway track at the uniform velocity for which the outer rail was elevated, and is therefore, by reason of centrifugal force due to this velocity, to gravity, and to the radius of the track, traversing the track in a state of equilibrium, the fluid will be of the same height in the branches of the U-shaped tube that it would be if the car were on a straight track having its opposite rails on the same level plane.

Again, if such a U-shaped tube, filled with liquid as before described, be placed on its base longitudinally with the axis of the car, as for instance on a side window sill, and if note be taken of

the height at which the fluid stands in each branch when the car is on a level grade, then whenever the car is moving along the line at a uniform speed on a descending or ascending grade, the variation in height of the fluid in the branches of the U-shaped tube from that indicated when the car is on a level track, will be an index from which the rate of ascending or descending grades over which the car passes can be approximately determined; and

Again, with the tube resting as last described, and the car moving over the track with a gradually accelerating or retarding velocity, the mechanical effect of such acceleration or retardation will be shown by its effect in overcoming inertia of the fluid within the tube, causing the fluid to rise in one branch with a corresponding lowering of it in the other.

It will be observed that the fluid in the simple U-shaped tube I have hereinabove described, conforms, under the conditions mentioned, to well-known statical law, no demonstration of which can be required. For several reasons, however, such a tube without important modifications is not of value for the purpose desired to be accomplished by my device. If the tube were to indicate clearly small increments of difference in level, its size would be too great for convenient use; and, again, if the tube had a uniform caliber, every shock caused by small inequalities of track surface, by the passing of joints of tracks, or by wheels not exactly cylindrical, under car would cause such motion or fluctuations of the liquid in the tubes as to render it impossible to observe the height of the fluid in the tube with that degree of accuracy desired.

The object or purpose of the instrument brought to your notice is to determine the differences of level in track laterally; to determine whether the outer rail of a railway track is elevated properly on curved line; approximately to determine the rate of ascending or descending grades of a railway line while passing over it in a car, and also to determine the mechanical effect of accelerating and retarding forces.

Though that part of the instrument which embraces the particular features to which your attention wlll be called can be made wholly of glass or of iron or of steel, except certain indicator tubes, which should be of glass, the description of this portion herein offered will be described as made wholly of glass, as follows:

Figure 427 represents a continuous glass tube, A, B, B', A', C, of varied calibre. To these various portions of differing calibre I will give names corresponding to the duties of each, and in fact I shall mention them as separate tubes, as they are such before being welded together as shown in Fig. 427. The tube C I term the "Retarding" tube; A and A' are termed "Accumulating" tubes, and should be of approximately equal calibre; B and B' are "Indicator" tubes, with uniform calibre, smaller than that of A and larger than that of C.

Tubes A and A′ should be alike in calibre between e, f and e′, f′, and between e, d and e′, d′ said tubes are reduced to the size of and welded to Retarding tube C, approximately in the form as shown in the aforesaid figure. The said Accumulating tubes A, A′ are also reduced in calibre between f, g and f′, g′ to the calibre of the Indicator tubes B, B′, and welded to same, as shown in said figure. At near h and h′ the Indicator tubes are bent and made to assume the approximate form as shown between h, i and h′, i′.

At i and i′ is welded an inverted U-shaped connecting tube

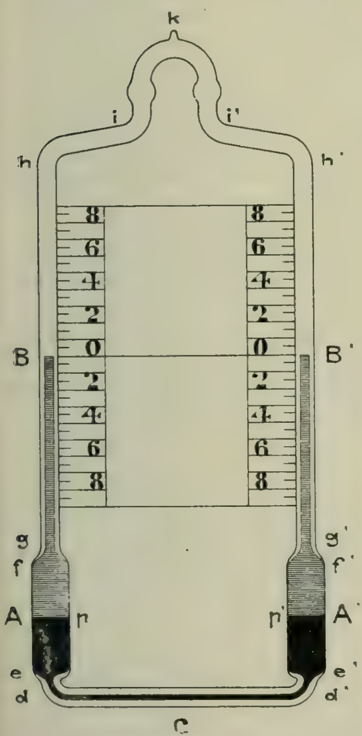


FIG. 427. "EQUILIBRISTAT."

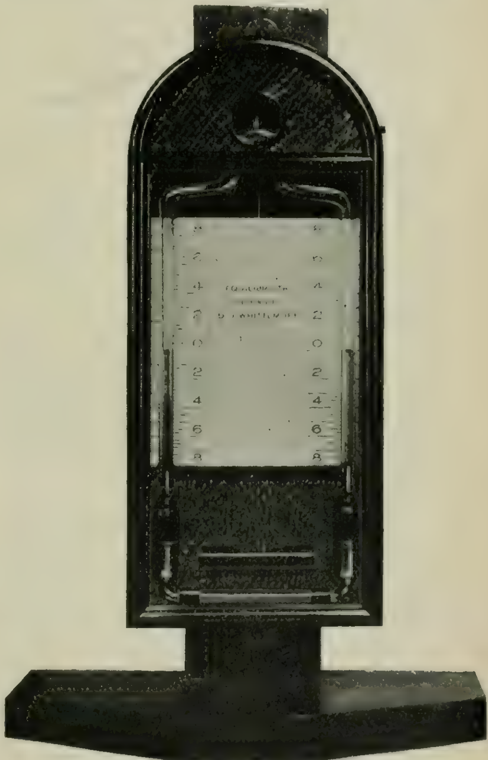


FIG. 428. "EQUILIBRISTAT," mounted.

which in its original construction has at K a small funnel formed or blown and which is not shown in the figure.

Immediately above i and i′ in the two branches of this U-shaped tube its calibre is enlarged, as shown in the figure, for a purpose which shall hereafter appear.

When the several tubes are welded together end on end, and the whole brought to the shape indicated by the figure mentioned, with its varying calibres, each communicating with the

other, the while is held erect with the Retarding tube resting on a level plane, mercury is introduced through the funnel before mentioned, filling the Retarding tube, and also to one-half the height of the Accumulating tubes A, A′, being at p and p′, as shown in Fig. 427. When this is done, pour through the funnel into the tube tinted alcohol or other light liquid which will not act chemically on mercury, and which will not congeal at ordinary temperature, until the balance of the Accumulating tubes A, A′ are filled, and also the Indicator tubes to one-half their height, say to m and m′, as shown by the figure, being careful to do this filling when the temperature is about 60 deg. Fahrenheit. When the filling as above described is completed. the funnel is nipped off and the aperture is hermetically sealed with the blowpipe, forming a nipple, as shown by the aforesaid Fig. 427 at K.

In this device it is not necessary before sealing to remove the air that remains in the indicator and connecting tubes above m and m′. This continuous tube containing the fluids as above mentioned should be kept in store for some months to permit that molecular change to which all freshly blown glass is subject, and which affects its calibre. This period of rest can be shortened by annealing the device before filling.

This continuous tube of various calibres, filled as aforesaid, is mounted in a suitable frame, and a scale plate is inserted between the indicator tubes B and B′. This scale plate has a line drawn horizontally across its face from o to o′, which is termed the zero line. By the tangent screw, not shown, the scale plate can be raised or lowered at will so as to have the zero line brought to coincide with the top of alcohol columns in indicator tubes, no matter what variation in the height of these columns variations of temperature may cause.

Should more alcohol be found in one indicator tube than in the other, as will happen occasionally, the inequality may be corrected by inclining the device sidewise, thereby allowing the mercury to pass from one Accumulating tube through the Retarding tube to the other Accumulating tube over which there is a surplus of alcohol. Thus the supply of alcohol will be forced over, across and through the inverted U-shaped tube to the Indicator tube where the alcohol is deficient, and when the device is again brought to an upright position a modicum of alcohol will be left in the enlarged calibre or bulb of the U shaped tube through which the air below will pass, thus permitting the alcohol in said bulb to run down the Indicator tube where alcohol is wanted. By this mode of manipulation the alcohol can be easily adjusted so as to stand at the same height in each tube when the base or retarding tube is level. It will be seen that if the device be inclined mercury will pass from one Accumulating tube to the other, thereby forcing the alcohol up in one Indicator tube, and causing it to fall in the other. The amount that the alcohol column will rise in one Indicator tube with a corresponding fall

in the other, is dependent upon the inclination of the device sidewise, the relative specific gravity of alcohol and mercury, and the ratio that the area of the calibre of the Accumulating tubes bear to that of the Indicator tubes; and dependent also, when the device is carried upright with the retarding tube C transversely with the axis of a car moving in a circular orbit, upon the action of centrifugal force thus generated upon the contained mercury. When the instrument is carried upright, and with the tube C parallel to the axis of the car, the ascending and descending gradients in the line of railway also have a share in determining the difference in the heights of the two alcohol columns. The height of alcohol in said tubes will be affected in a similar manner when the instrument placed as last mentioned is subjected to gradually retarding or accelerating velocity of the car moving over a line of railway.

The most useful purpose of this instrument is, however, to ascertain whether the two opposite rails of a railway track are on the same transverse level on tangent lines, and whether the outer rail on curved lines of track is properly elevated above the inner one to suit the speed of passing trains.

For the purpose last above described the instrument may be so proportioned in the different parts that when the Retarding tube is inclined to the same angle that one inch elevation of one rail above the opposite rail makes from horizontal or level line, the mercury in flowing from the Accumulating tube through the Retarding tube to the other Accumulating tube will cause a rise of alcohol in the Indicator tube immediately connected therewith of about three-tenths of an inch. This may be considered a convenient unit into which the scale attached to the device may be divided so that one unit of the scale will correspond to one inch of super-elevation of one rail of the track above the other opposite. This unit of the scale may be made greater or less if desired by properly proportioning the parts.

Anyone desirous of manufacturing this instrument on a plan to accomplish the object above mentioned, will find the formula hereinafter given useful in determining the general dimensions of the several parts of the continuous tube made up of several tubes of different calibre.

The calibre of the Indicator tubes need not be more than about three thirty-seconds of an inch to enable one several feet away to determine with the unaided eye the position of the alcohol column, in reference to its top, as shown by the scale described, to such fraction of its unit as is desired for practical purposes.

With the Indicator tubes of the calibre above mentioned, I have ascertained that by having the calibre of the Retarding tube C, such that about 5 inches of it will contain as much mercury as would be contained in one inch of the Indicator tube, or in other words by having the sectional area of the latter about five times greater than that of the Retarding tube, the mer-

cury in passing from one Accumulating tube to the other to adjust itself to impulses caused by those frequent shocks of differences of level that occur many times a second when a car is moving with any considerable velocity, would, by reason of resistance to the rapid flow of mercury through the small calibre of the Retarding tube, be so retarded that before but a fraction of such effect could be communicated from one Accumulating tube to the other, this effect would be negated in a great measure by opposing shocks, so that only those differences of level that exist for some space along the track would be clearly shown by the rise and fall of the alcohol in the Indicator tubes, without any disturbing fluctuations caused by minor, frequent shocks.

In case the retarding tube is made of metal, its calibre need not be contracted, as the object can be more easily attained by inserting anywhere in its length a reducing cock, whereby the aperture for the flow of mercury through the tube can be reduced at will to any extent desired.

The unit employed on American railways to express what should be the super-elevation of outer rails on curves is the inch.

For the purpose of determining the snper-elevation of rails on railway curves or on tangents, with that degree of accuracy desired, the width between the centers of the two Accumulating tubes need not be much, if any, over four inches, and assuming that this width is also known, there remains to be determined what the ratio should be between the sectional area of the Accumulating tube and that of the Indicator tube to cause the alcohol to rise one scale unit in one Indicator tube with a corresponding fall in the other whenever the inclination of the Retarding tube C corresponds to the inclination caused by raising one rail of a railway track one inch above its opposite rail.

While it is not necessary that both Accumulating tubes be of the same calibre, it will be found convenient to the manufacturer of the instruments to have them so, and in this event the instrument may be proportioned so as to satisfy the following formula, in which

W = Width between centers of Accumulating tubes.

R = The ratio that the sectional area of the Accumulating tubes bears to that of the Indicator tubes as unity.

S = The specific gravity of tinted alcohol or other light fluid used.

M = The specific gravity of mercury.

G = The gauge of the railway track measured from the center of one rail to the center of its opposite.

U = The scale unit in its decimal of a unit or other lineal measures.

FORMULA.

$$W = 2GU\left(\frac{S}{M} + \frac{1}{R}\right)$$

Assuming that the standard railway gauge of America is 59 inches measured as above stated, that the unit of the indicator scale desired is $\frac{3}{10}$ of an inch, that the ratio which the cross sectional area of the Accumulating tubes bears to that of the Indicator tubes is 20, that the specific gravity of mercury is 13.58 and that of tinted alcohol is .834, then, by the above formula, the width between the Accumulating tubes is ascertained to be 3.94 inches, a width amply sufficient for the purpose desired in ascertaining transverse differences in level of railway track.

It is readily ascertained that if the instrument is proportioned with the ratio between Accumulating and Indicator tubes as above stated, and the calibre of the Indicator tubes is $\frac{3}{32}$ of an inch, then the calibre of the Accumulating tubes should be about $\frac{5}{12}$ of an inch to make the ratio between them 20.

If the device is intended for determining gradients in the line of railroads, or for indicating the effect of retarding or accelerating forces, the proportions of the instrument should be changed to suit that class of work. Great care should be taken that the Indicator tubes have like and uniform calibre, and this can be best ascertained by passing along the tubes a short column of mercury. If the calibres are alike and uniform the mercury will preserve a constant length.

However carefully the several tubes that form parts of the continuous tube are selected and joined together in the form shown in Fig. 427, whether the whole is made of glass, or in part of glass and part of metal, to insure accuracy the Indicator tubes must be calibrated experimentally, and this is accomplished as follows:

First, adjust the alcohol in the two Indicator tubes so that it stands in each at the same level when the Retarding tube C is level.

Second, adjust the scale plate between the two Indicator tubes so that the zero line corresponds with the top of the alcohol column in each Indicator tube; then give the Retarding tube C an inclination corresponding to such inclination as would be caused by raising one rail of a railway track one inch above its opposite rail, and then note on the scale-board to what point the alcohol rises in one Indicator tube, and to what point it falls in the other. Continue the process for each successive inch of superior rail elevation until a maximum of nine inches superior elevation is reached. After this bring the instrument again so that the Retarding tube is level, and thereafter give the instrument such inclination in the opposite direction as would be caused by a similar elevation of the opposite rail, noting in each case the points reached by the alcohol columns on the scale plate. When this calibration is done and the units on the scale plate are shown, the same units can be subdivided into such fractions as may be desired by interpolation.

The scale plate should be long enough to cover about nine units above, and the same below zero line, nine inches of superior ele-

vation of rails on standard gauge tracks of America, being abou the maximum in general practice. The calibrated Indicator tubes, however, should be about twenty-two of the scale units long, so as to permit the scale plate to move at least two units up or down from where the alcohol will stand in same at normal temperature of 60° Fahrenheit. In this way the zero line of scale plate may be adjusted to coincide with the top of alcohol columns at other temperatures.

While making tests with this device, should the temperature not change over about 3° Fahrenheit, no readjustment of the scale plate will be required. Any change caused by change of temperature is easily detected by the unequal records of the two tubes.

Though it is not necessary to have the calibre of the Accumulating tubes uniform beyond the space through which the mercury ranges, yet it will be found convenient, in an instrument to be used in determining superior elevation of rails of railway track, to have the calibre of the tubes uniform for a distance equal to at least one-fifth of the width they are apart between centers.

It is not necessary that alcohol or other light liquid should be in more than one of the Indicator tubes, in which case the scale will be single. The reason that the use of alcohol in two Indicator tubes is recommended, is that it affords an easy method of detecting any change in volume that may occur during use through changes of temperature, while if one Indicator tube is used, observations must frequently be made to see if the single column reaches zero of the scale when the instrument is level.

Some, however, may prefer to make the instrument with alcohol or other light liquid in only one Indicator tube, because the instrument when thus made is more compact laterally, and because the sectional area of the Accumulating tubes need not have so high a ratio to that of the Indicator tube as prevails when the two Indicator tubes are used, even though the distance between Accumulating tubes be the same in the two styles of instrument. This appears from the following formula for the style with only one Indicator tube. The designating letters used before are here repeated:

$$W = 2\,G\,U \left\{ \frac{S}{2M} + \frac{1}{R} \right\}$$

With either form of the instrument properly placed and adjusted, as the car moves along and over the track on tangent lines, the rise and fall of the alcohol in the Indicator tubes will indicate correctly any transverse variations in the level of the two opposite rails. Again, when the car with the instrument passes along and over a curved line at so slow a speed as not to generate centrifugal force to any appreciable extent, the alcohol column by its rise or fall will indicate the extent of superior elevation of the outer rail over the opposite or inner rail of the curved track

passed over; but if the device is being carried over the curved line at a high and uniform velocity, and the outer rail of said track has been elevated above its opposite a proper amount, the alcohol in Indicator tubes will register zero on the scale, and if the curved track has its outer rail improperly elevated for such velocity, the mount of such improper elevation will be shown by the extent the alcohol column stands above or below zero, as shown by the scale units.

I should mention that the above remark is not strictly true, in so far as it is subject to centrifugal force, as the air in the tube connecting the tops of the Indicator tubes, and which was left in same at atmospheric pressure when the instrument was hermetically sealed, is also influenced by the force which acts on the mercury, and which tends to negate the action on the latter in the proportion which the specific gravity of air bears to that of mercury, both estimated on the same basis; hence it follows that there is present an error which can be represented by a fraction having for its numerator the specific gravity of air, and for its denominator the specific gravity of mercury, this being approximately $\frac{1}{11000}$, a fraction that cannot be measured by the instrument and therefore can be disregarded entirely.

It is evident that this minute error can be wholly eliminated by producing a vacuum in the tubes above the alcohol at the time of hermetically sealing, a refinement entirely unnecessary in an instrument designed for the purpose above mentioned.

It is notorious that a curved track having its outer rail elevated so that a train passing over it at a certain desired and uniform velocity will be in equilibrium, does not remain so elevated for any considerable length of time. Heavily loaded freight trains passing over such a track at slower speed throw a preponderance of weight on the inner rail, thus causing it to settle in the yielding ballast more than the outer one; again, traversing the curved track at a higher velocity than that for which the track was adjusted, brings a preponderance of stress on the outer rail and tends to depress the same in the ballast more than the inner rail, hence changes occur that should be corrected from time to time.

When properly placed and adjusted in a business car it will afford valuable and accurate information to the manager, superintendent or engineer of maintenance of way as to the condition of the track in respect to undue or insufficient elevation of one rail over its opposite; and again, when the device is properly placed on hand or velocipede car, or a vehicle constructed for the purpose, and passed slowly over the track, the roadmaster, inspector of track or section foreman can readily observe the transverse conditions of the track passed over more accurately and at less trouble and expense than by the prevailing methods.

The instrument can be enclosed and mounted in a metallic case (see FIG. 428) 5½ inches broad, 12 inches high and 1¼ inches deep, and can be permanently fixed convenient for use to the door-post, alongside the rear observation window of a business car.

Track inspection by observations from the rear end of a business car is at best crude, and not always satisfactory, but by the added aid of this instrument facts in regard to lateral conditions can be easily ascertained, thus making such mode of inspection vastly more valuable than those that have heretofore prevailed.

I have made repeated trials of the device, the last extending over about 800 miles of railway, on some of which curves ranging from 3° to 8° were passed over, many of which were known to have outer rails elevated properly for the speed at which they were traversed, and in every such instance the instrument registered approximately zero, as it should. In trial one of the first evidences it affords is that curves should be spiraled and that the super-elevation should be made on and in degree as the spiral approaches the degree of the curve which it subserves.

From my observations I find that the varied loading which will occur through change of position of six or eight adults in a business car does not appreciably affect the accuracy of the instrument, but high side winds undoubtedly would do so.

This instrument will be found useful in detecting erroneous alignment of curved track. On some lines curves have not been recentered instrumentally since the original construction of the railway, and in the meantime, through various causes, lateral displacements affecting the alignment have occurred, making it sharp in some places and flat in others. On such a curved track, adjusted for a uniform speed as originally laid, the instrument will certainly indicate the errors of alignment by undue fluctuations caused by changes in centrifugal force, and determine at once that the curved track should be instrumentally adjusted.

Again, we will suppose the curved track to be known to be truly circular, with its outer rail properly elevated for a stated speed, then when passing over same at a higher or a lower uniform velocity than that for which the super-elevation was made, a close approximation to higher or lower speed can be determined by observing the position of the alcohol column above or below zero as the case may be.

For railways of standard gauge (59 inches center to center of rails) the formula commonly employed in determining super-elevation of rails may be simplified, employing terms usually used in railway parlance, namely:

E = Super-elevation in inches.

D = Degree of curve, and

V = Velocity of train in miles per hour as follows:

$$E = \frac{DV^2}{1450}$$

In ordinary railway practice the slight error in this formula, caused by assuming that the cosine of angle of inclination equals radius, may be neglected.

DISCUSSION.

Prof. Whitney: I would ask Mr. Whittemore if he proposes that engineers of maintenance of way or road-masters use this in checking the work of the foreman and in perfecting the road?

Mr. Whittemore: That is certainly the main object, that road-masters and engineers of maintenance have these instruments. They need not take the word of their section foreman as to condition of track, but take it on a hand-car and note as the car proceeds just how the curve is. They can note it absolutely and much more accurately than they can do it ordinarily with the level boards. There is hardly any level board that a section man has had a month that is accurate.

Prof. Whitney: About what will be the cost of one?

Mr. Whittemore: The continuous tube filled, sealed and calibrated will cost approximately four dollars, and one can spend as much as he pleases for the case. One properly mounted and suited for a business car may cost fifty dollars, and one suitable for road-master's use about half as much.

Mr. Kramer: Does the swing of the car make any difference in the operation of the machine?

Mr. Whittemore: Violent swings, the impulse of which covers half a second or more of time, would be shown. In fact, it is the purpose of this instrument to be affected by marked swings, as such ordinarily result from imperfect track; but the swings or shocks that occur many times a second, when the train is moving with any considerable velocity, do not materially affect the work of the device.

CORRESPONDENCE.

By C. L. Crabbs, Mem. W. S. E.

The "Equilibristat," as described, will prove to be, without doubt, of great assistance to the official whose duty it may be to investigate surface conditions of railroad track.

It would seem, however, that in the use of the instrument in an ordinary work there is a possibility of error in determining lateral differences in level of curved track, arising as follows. The body of the ordinary car rests upon a more or less flexible base. It may be moved from its normal horizontal position by a lateral or tipping force, the amount of such tipping depending not only upon the degree of force applied, but also upon the flexibility of truck springs, the amount of play between side-bearings, etc. If, then, the instrument be mounted in such a car moving over a curved track, the outer rail of which is not sufficiently super-elevated for the speed at which the car is moving, the reading of the scale may not be a true index of the amount of super-elevation to be added to the curve, owing to an improper position of the scale card with reference to the plane of the track. It seems self-evident that the scale reading, in the case

of a car with flexible base laterally, will not be the same as in that of a car carried rigidly on its wheel base with the same conditions of track and speed. It is admitted that the device will indicate accurately a *correct* lateral condition of track.

The question arises: Will the error, from the source suggested, be of such small moment as to be disregarded in the practical handling of the instrument? Will it not be necessary to apply a correction to the reading of the instrument, when used to determine errors in super-elevation on curved track?

The expression representing such correction will necessarily include the value of lateral effect of centrifugal force, depending upon speed, degree of curvature, etc., and that of compression of truck springs per unit of load. It might be tabulated for any particular car and applied to the scale readings by inspection, the only difficulty being in a determination of the speed at which a test of track is made. Again, a correction made necessary by centrifugal force may be applied mechanically in the instrument itself.

By Charles Paine, C. E.

The instrument devised by Mr. Whittemore, and to which he has given the name of Equilibristat, will be of great value to those who have in charge the maintenance of track, for it will afford them positive information in the easiest manner, where it has heretofore been attainable only by the tedious process of walking over the track with a level, or the use of expensive apparatus like the equipment of a few special cars, such as Mr. Dudley's, available for only one or two trips over a division in a year. Mr. Whittemore's invention should be available for each supervisor of track, who could take it with him several times a month, in any car in which he might be traveling, even on a hand-car; and I believe, so used, it would effect more in the perfecting of track than any instrument of precision which has been suggested for that purpose.

It is probable that the other use of the instrument suggested by the inventor, the determination of the rate of grade, might be of considerable benefit to the locomotive engineer, who seldom has anything to inform him of the change of gradient except the acceleration or retardation of his train. This is scarcely fair towards the man who is responsible for running with evenness, often upon a division with which he has little acquaintance. In Europe, on many lines, the intersections of gradients are marked by posts with small sign-boards attached, each inclined up or down in the direction of the grade, with its rate per cent painted upon it. For civil engineers or other observing travelers passing over new railroads, (or new to them), the information given by this second form of the instrument would be of much interest. The portability of both forms and the simplicity of their con-

struction seem to me to recommend the instrument, especially to *practical men*, using the term to designate those hard-headed men who are doing their utmost to secure for us perfect smoothness of transit as we read and smoke luxuriously in the softly cushioned car.

By N. O. Whitney, Mem. W. S. E.

Mr. Whittemore's pocket inspection car—the Equilibristat—certainly gives wonderful results. The poorest railroads should be materially helped in track improvement by the use of this simple, effective and inexpensive instrument in the hands of every maintenance of way officer from track foreman to general manager.

I wish that the author of this particularly lucid paper had explained one matter, which it seems to me is quite pertinent, viz., the centrifugal effect of the car body on the car springs as influencing readings of the Equilibristat taken when transverse to track during speed on curves. It has been my understanding that the weight of the ordinary car body compresses the springs four to six inches; and that during speed on curves the outer springs, by reason of the increased weight due to centrifugal force, may be compressed about two inches more, while the inner springs being correspondingly relieved, would expand the same amount. If this is true, will not this movement of car floor relative to wheel base materially affect Equilibristat readings? Will not stiff car springs, or absence of all springs, cause different readings from those produced by weak springs on the same track and at the same speed? It seems to me this varying movement of the car floor must produce an effect on the readings independent of that produced by the centrifugal force upon the liquids in the tube.

CLOSURE.

By D. J. Whittemore, Mem. W. S. E.

The possibility of errors through the use of the instrument in business or other cars resting on springs, mentioned by our member, Mr. Crabbs, is admitted, the amount of which can be easily determined as applied to the particular car used, simply by first adjusting the instrument to record zero when the car is on a level track; then moving the car to a track, one rail of which has a known super-elevation and noting the reading of the scale, the variation or error can then be noted and duly proportioned.

The car used in making my tests indicated that the error caused by spring movement, if any, was very little; as for instance, in several tests on a 2° curve which had a superior elevation of outer rail of 2.2 inches, suited to a speed of 40 miles per hour, when passed over at a speed of 60 miles per hour, the instrument re-

gistered from 2.7 to 2.9 units above zero, indicating that the outer rail should have that number of inches greater elevation, or a total of from 4.9 to 5.1 inches, whereas 5 inches is the correct superelevation for a 60 mile speed.

I believe that for such inspection as is required through the agency of a business car the showings of the instrument can be taken as close approximations, and when used on hand or other cars that have no spring supports, it will be found absolutely correct, and it is on these latter that I surmise its greatest utility will be found.

XLIV.

CABLEWAY AT LOCK AND DAM NO. 2. MISSISSIPPI RIVER IMPROVEMENT.

By R. D. Seymour, Mem. W. S. E.

Read September 7, 1898.

The subject of cableways is doubtless rather an uninteresting one to those members of the Society who used the travelling machines of this kind on the Chicago Drainage channel, but the machine I wish to call attention to this evening is one which shows such a decided improvement, both in construction and manner of operation, over anything previously attempted in this line, that it was thought worthy of your attention.

Lock and Dam No. 2, as it is locally known, is one of a series of four, designed for the improvements of navigation in the Mississippi river between Minneapolis and St. Paul by the U. S. Engineer Corps under appropriations made by Congress in the River and Harbor bills. The designing and execution of this work is under the direction of Major Frederic V. Abbot, Mem. Am. Soc. C. E., who is in charge of the St. Paul office.

Fig. 429 is a general view of the river taken from the east end of the Air Line Bridge, which crosses the river 1200 ft. north of the site of the lock and dam. The bridge shown in the background is the Marshall avenue bridge, which is about one-half mile below the point of view. The stage of the water when this view was taken was about two feet above low water mark. The obstructions shown in the river are floating logs on their way to the sorting booms near St. Paul. The river here is about 700 ft. wide, and as shown, the banks are high and abrupt, and all the material used in construction has to be assembled on the east bank and used as needed, except the filling for the coffer dams, which is to be taken from the lower level of the west bank, shown on the right of view. The lock wall and piers and foundations of the dam are to be built of concrete which is to be mixed on the east bank. The quick and reliable handling of the large quantities of materials to be used under the conditions existing on this work was a problem directly in line with the well-known advantages of cableways for covering large areas regardless of surface difficulties, and one was therefore selected as the most economical machine for this work.

Competitive designs and estimates for the machine required were asked for from the different manufacturers in this line, and after careful consideration, the one offered by the Trenton Iron Company, of Trenton, N. J., and which is the subject of this paper, was accepted by Major Abbot, who personally inspected the erection and operation of same.

Fig. 430 is a near view of the head tower of this cableway, with a

three ton load of timber hoisted and ready to be sent out to where needed in the river. The height of this tower is 55 ft. above rails. The four main posts are made of 12 in. x 12 in. timber, and are each in one piece. The cross bracing and ties are 3 in. x 12 in. of the same material securely fastened to posts with ¾ in. bolts. The trucks are made of standard gauge carwheels arranged in sets of four wheels under each leg of tower and eight wheels distributed evenly on rear tracks to carry counterweight. The platform, to which the trucks are rigidly attached, is 56 ft. long and 32 ft. wide, made of 12 in. x 12 in. sills and covered with 3 in. planking, spiked on. The section under the engine between rear and center trucks is trussed with 1½ in. rods. The timber used was Oregon fir and the carpenter work thereon was decidedly high grade. The vibration when worked at maximum speed, which contributed largely to wear and tear of machines used on the drainage channel. was hardly noticeable in this case. The stress in this tower caused by the long span of 1150 ft. (which I think is the longest that has so far been used with movable towers), and the maximum load of five tons made it necessary that the tower should be constructed in the strongest and most substantial manner, and results show that the slight extra cost of this grade of work is warranted. The engine used and shown in view is a double tandem friction drum engine, with reversible link motion and 10 in. x 12 in. cylinders. It is geared to give the required rope speed with 100 lb. steam pressure. The boiler used is what is commonly known as a Scotch Marine with internal fire box. It figures up 60 H. P. and proved well able to keep its end of the combination up while machine was being tested under specified conditions of load and speed in handling the same.

The cable used is 2 in. in diameter, and is the Elliott or Patent Locked Wire made by the Trenton Iron Co. It is anchored to towers with adjustable anchor tackles on both ends. One of the blocks of this tackle is shown in view about 30 ft. above the platform. The reason for having this cable anchored in this way was because the loading point of nearly all the material to be handled was in one spot, and as the wear of the cable is much greater at that point than at any other on the line, it was made one of the specifications in contract that it be put up so that this point could be changed when needed. This is a new idea and I believe a good one, as it cannot fail to lengthen the service of a rope of this kind. The amount of adjustability that can be put in a machine of this kind is limited by the height of the lowest tower. In this case, on account of the tail tower being only 30 ft. high, it is something less than that amount.

The traversing carriage shown on the cable in this view is of the regular three-sheave kind, but it will be noticed there are no fall rope carriers on it. The absence of fall rope carriers and the button rope is one of the distinguishing features of this plant. Any one who has ever operated a cableway will

Fig. 429. Site of Proposed Lock and Dam No. 2.

Fig. 430. Head Tower of Cableway at Lock and Dam No. 2.

doubtless remember the trials and tribulations, also the extra expense caused by fall rope carriers, both of the connected kind and the kind which needs a button rope to space them properly.

The hoisting line in this case is run around an elliptic drum on the engine in the same way as the hauling line. The hoisting is done from the opposite direction, and the slack of the hoisting line is held up when load is landed by the slack side of line which is attached far enough back of end of same to leave enough rope to reeve through blocks and give the amount of hoist required. There is a varying tension in this line caused by the loading and unloading which is governed by the weight box shown in the tower.

In order to have this hoisting line continuous and to prevent twisting with the endless part of the same, a patented double swivel attachment is put on where the end is attached to the bight. When the ropes were first installed these lines showed a disposition to twist and interfere with each other, but after the machine was operated a few times the swivels worked as it was intended they should and no further interference was noticed.

The hoisting and hauling ropes used in this plant are the regular ¾ in. x 19 wire cast steel hoisting ropes. These lines are smaller than those which are generally used in cableway work. They are large enough for the service required here, and as they are not subjected to the wear caused by being run through carriers, will give as long service as the ⅞ in. ropes usually put on machines of this kind. The view, Fig. 2, shows the way these lines lead when load is in position near tower. The highest one is the tight side of hoisting line. The next one below is the endless or traversing line. This line appears to be below the other, owing to the fact that the view was taken from the ground level. They run out of the tower from sheaves that are level and are separated 36 in. horizontally. The line shown below the two above mentioned lines is the slack side of hoisting line. It is attached to the bight of hoisting line 220 ft. from carriage, and the hoisting end can be seen reeved through carriage sheaves and fall block. The line below the cable is the traversing line and the attachment of ends of same to carriage can be noticed in view.

Fig. 431 shows the right of way and tracks over which the head tower travels while in service. These tracks are 650 ft. long, and are long enough to allow cableway to cover the entire length of lock walls and the coffer dams required above and below same. The right of way shown was, owing to limited space allowed, a very narrow one, being only 57 ft. wide. This, I think, is the narrowest right of way over which a 55 ft. movable cableway tower has ever been operated, and for this reason it was necessary that the tracks should be constructed in the most substantial manner. They had not been completed when the view was taken, but enough is shown to give an idea of how the work was done. The two front tracks which carry the weight of tower and stand most of the thrust caused by the tension of cables and are

spaced 18 ft. between centers. 65 lb. steel rails were used with cedar ties, which are spaced 18 in. between centers. Every fourth tie is an 8 in.x8 in. timber extended through so as to tie both tracks and keep them in line with each other. The center of the rear track is 24 ft. 11½in. from the center of middle track and is constructed in the same manner except that it is tied to the others by 8 in.x8 in. timbers, which extend across right of way at every sixteenth tie. The most approved kind of rail braces are used on the outside lines of rails in the direction of thrust. These are securely spiked to every other tie. They cannot be seen in this view, but are shown very plainly in Fig. 430. The ground on which these tracks were built is a deposit of glacial drift mixed with soft clay and muck. It was very soft and wet, caused by a swampy depression back of the bank shown on the right hand side. The problem of proper drainage for this right of way was solved by the ditch shown, which was dug down 6 ft. to bed rock and curbed and braced. It was put in as shown in view and left open to insure positive drainage. The seepage from the bank and storm water is carried to the river through a pipe drain laid under tracks, which is large enough to take care of same under any ordinary conditions. This ditch proved in practice to be a very satisfactory solution of the drainage problem. The tracks were accurately lined to fit the gauge of the tower trucks and made as near level as possible. The towers can be moved to any point desired with a very slight expenditure of power.

Fig. 433 is a distant view of the head tower taken from a point on the bank about 300 ft. north of the same. It is given to show how the lines lead from the tower when load is in the centre of span. Fig. 434 is taken from the same point and shows the other end of the span with the load and carriage about midway between towers. It also shows the method of attaching hoisting line,and how it is kept up without the aid of fall rope carriers. Fig. 432 is a near view of tail tower, which, owing to difference of level of banks of river, is only 30 ft. high. This tower is on the west bank of river, and as a right of way was limited only by what was needed to get proper proportions of tower, the tracks could be spaced in a little better proportion to height of tower. The tower tracks on this side are 13 ft. between centers and the center of counterweight track is 16 ft. 11½ in. from center of middle track.

The same style of construction was followed here as previously described for the head tower; no difficulty about drainage was encountered, as the right of way is on a solid, well-drained clay bank. The large sheave shown back of the head timbers of the tower is the one around which the hoisting line passes. As the swivel connection on the hoisting line has to pass around this sheave, a wide groove and large diameter was preferable to the two small sheaves shown in view which carries the traversing rope. This swivel connection, previously described, will not have to touch this sheave, except when carriage is within 200 ft. of tail tower, which

FIG. 431. RIGHT OF WAY AND TRACKS FOR HEAD TOWER, LOCK AND DAM NO. 2.

FIG. 432. TAIL TOWER, CABLEWAY LOCK AND DAM NO. 2.

will be found to be very seldom the case, as about 90% of the work to be done is in the middle of span and near east bank. The dimensions of the tower platform is 42 ft.x23 ft., and it is built of the same material and put together in the same substantial manner as the head tower previously described. The shed shown over the anchorage was built to protect from the weather the anchor tackle and coil of ⅞ in. line used in adjusting same.

The time used in the erection of the machine was 31 days of 8 hours each. Had it been necessary, the work could have been done in much less time, but owing to the weather and unexpected delays in the delivery of timber used in towers, for which extensions of time were granted, the work was delayed.

In adapting the cableway to the work under his charge, Major Abbot has shown what a relatively enormous area can be covered by a machine of this kind. The total area covered by this machine, including right of way for tracks, is 18 acres; the tracks and towers take up an acre and a half of this, leaving sixteen and a half acres, any point of which can be reached by the fall block hook. When we consider that a large part of this area is the roughest and most inaccessible surface imaginable, many points of which it would be impossible to reach economically with any other form of conveyor, and that a five ton load can be taken from or delivered to any point within the bounds mentioned at a speed of 800 ft. per minute, with perfect safety to operators and machine, it shows the capabilities of a cableway in this line in a very substantial way.

The construction of Lock and Dam No. 2 is a work that cannot fail to be of great interest to the members of the Western Society. This work will be carried on through the next two working seasons and will not be completed until the latter part of 1900, and as the cableway had been very thoroughly tested and proved in service to fully meet the requirements of the work to be done, it was decided to call your attention to this part of the plant now, and follow later with another paper on the record made and a general description of the work done.

DISCUSSION.

Mr. Bainbridge: Will Mr. Seymour explain how the tower platforms and weight cars are moved?

Mr. Seymour: The cableway will not be put in active service this season. All of the work to be done with it this year is preparatory work, and the towers will not have to be moved until the work in the river is commenced next spring. When needed a haulage plant will be put in to move the towers to any position desired. This plant will consist of a small double drum winding engine placed on the platform, and wire rope tackle blocks which will be anchored to the platform and at both ends of track. This arrangement will move the tower in either direction and hold it in position while at work. The plant for the tail tower will be the

same except that the power will be applied through a suitably geared "winch" which will be operated by hand.

Mr. Wisner: What is the cost of a machine of this kind?

Mr. Seymour: I cannot give the exact figures as the erection was done with labor furnished by the officers in charge of the work and the cost of the same has not yet been accurately figured up. The conditions under which this plant was installed were very favorable for economical handling of materials used in construction, and considering the quality of work done, the cost was comparatively low. The plant cost about $11,500.

Mr. Wisner: That would include the engine and boiler?

Mr. Seymour: Yes, the complete plant ready for operations.

Mr. Strobel: Does that cost of $11,500 include the cost of rails and tracklaying?

Mr. Seymour: Yes, sir.

Mr. Condron: Will Mr. Seymour please point out more clearly the arrangement of the hoisting line through the carrier?

Mr. Seymour: Figure 434 shows how the hoisting line is arranged better than any other view we have. This view shows the west half of the span with the load about the centers of the same, and shows how the hoisting end of line is held up when the load is suspended ready for traversing. When the load is lowered, the point where lines are attached, about in the center of the view, approaches the carriage. As this part of the line is only 220 feet long the weight of the fall block is enough to hold it up without the aid of carriers. The rest of the hoisting line passes around sheaves in both towers, the same as the traversing line, and it can be given tension enough to hold it up above the cable as shown in the view.

Mr. Wisner: What is it that holds the deflection of the hoisting cable up?

Mr. Seymour: The weight of the fall block keeps the hoisting end up, and the deflection of the endless part of line is kept even in both strands by the weight box shown rather indistinctly in the tower in figure 430.

Mr. Wisner: Does the weight box have to have a separate cable?

Mr. Seymour: No, sir, there are only three working lines on the machine, the carrying cable, the hoisting line and the hauling or carriage line. One end of the hoisting line is attached to the becket of fall block and the other end is attached to the bight of the same line 220 feet from the fall block. This hoisting line is reeved through the hoisting sheaves of the fall block and carriage, it leads from the carriage to the under side of the large sheave shown on tail tower in figure 432, and leads from the upper side of this sheave back to the sheave shown on the top of the head tower in figure 430 and then passes down around the engine drums. From the engine it leads to a sheave under the head timbers of the tower, and then down around the weight, box sheave

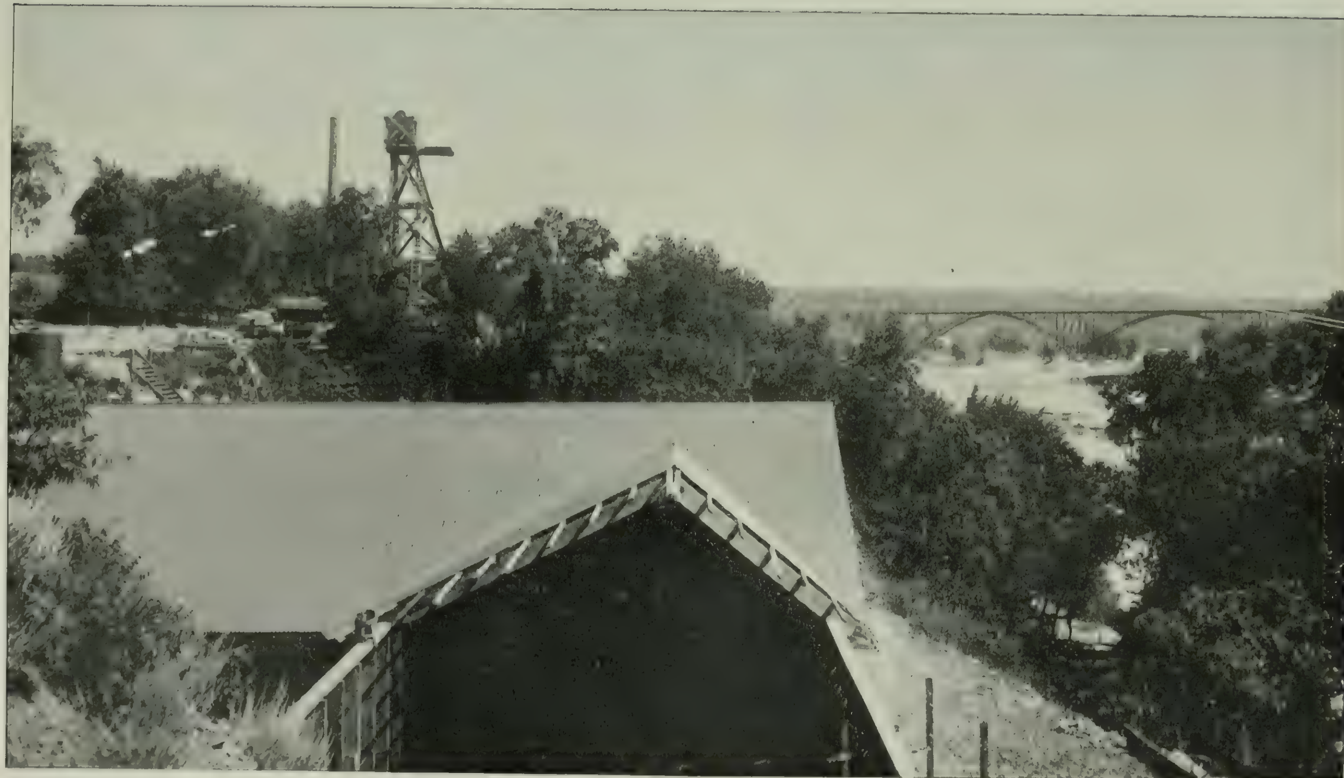


FIG. 433. EAST HALF OF CABLEWAY, LOCK AND DAM NO. 2. Showing Leads of Lines when Load is in Center of Span.

and back up to another sheave of the same diameter which runs on the same shaft, and then out of the tower to the point where it is attached to the bight of the hoisting line. When the machine is working, the tension in the upper part of this line varies, owing to extra tension added when the load is suspended, and as any variation in the tension raises or lowers the deflection, it made it necessary to have something to govern the deflection of the lower part of line. This is why the weight box was added, and it regulates the deflection of slack part of lines very efficiently regardless of any tension or change in deflections in the upper part of the line.

CORRESPONDENCE.

By W. H. Baldwin, Mem. W. S. E.

Mr. Seymour's paper is an interesting one, and I believe he is the first to call public attention to the method of supporting the slack of the hoisting rope, without the use of fall rope carriers. The plan, however, is not a new one, and is open to some objections, although there are some advantages in its favor.

The endless rope which moves the carriage back and forth need not necessarily be supported, because the two ends being fixed to the carriage its own tension maintains the normal sag or deflection. It is, however, a great advantage to use fall rope carriers, not necessarily to support the endless rope, but to keep it from fouling the hoist rope.

The plan suggested in this paper is to employ one endless rope to move the carriage back and forth, and a second endless rope, to which is spliced in a branch rope, which serves to hoist the load. It, therefore, is to be seen that the only part of the hoist rope that may be slack is from where it is spliced to the endless rope to the carriage. This is stated in the paper to be about 200 feet.

The objections that are to be raised against this plan for a cableway of the nature that the paper describes are two:

First, the employment of a winch-shaped drum, the rope making several wraps in order to obtain the requisite tension in the traversing of the load to and fro, and with the tension of the load upon it this drum will cut out very rapidly, and also wear out the wire rope far faster than any number of fall rope carriers possibly could. Furthermore, this endless rope is constantly under the tension due to its own weight; therefore, when the carriage is running empty and when it is running loaded there is always a great deal of strain on this endless rope, and it is for this reason that, whenever possible, the use of this winch-shaped drum for propelling the carriage should be avoided. Whenever possible, the carriage should be propelled back and forth by an in-haul and outhaul rope, one rope winding on the drum while the other is unwinding from the same.

The other objection to this plan is the swivel joint required for

joining the branch hoist rope to the endless rope. This rope might be spliced in were it not for the fact that the endless rope and hoist rope both twist considerably, and therefore in winding the hoist rope around the endless rope the machine shortly becomes inoperative, hence the necessity of a swivel joint. This swivel joint must of necessity be considerably larger than either the endless or hoisting rope, and in consequence requires a very large diameter sheave wheel to run over, and it is a question whether, however large the sheave may be, the rope will not be injured by passing over it.

If there were no other way of supporting the hoisting rope than this, then these objections would have to be waived and the consequences suffered.

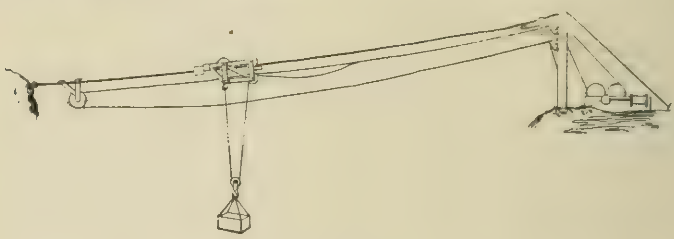


FIG. 435.

This idea was invented by Mr. Spencer Miller, C.E. Fig. 435 is reproduced from the patent office drawing, which was issued him July 5th, 1892. The plan has been tried on two or three different occasions in handling logs in the swamps of Louisiana, where it was impossible to use the fall rope carrier and button rope. The cableways used for handling logs had a span of about 700 feet, and are only used for a few hours in one position, when all the ropes are moved to a new position. Under such circumstances this plan is the best that can be employed.

The two years that this cableway is to be used may demonstrate the fact that the objections which have been offered to this system are no more serious than those which occur with button stop fall rope carriers.

One more point I wish to make before closing, and that is, that the ordinary cableway is not obliged to handle the twentieth part of the material that the cableways were required to handle on the Chicago Drainage Canal, and the fall rope carriers are now designed after the experience had on the Chicago Drainage Canal, and are capable of standing a very much harder service than those that were employed during the construction of the canal, and I question very much whether the cableway described in this paper will see anything like the service that was expected from the machines on the canal, and consequently it will be difficult to establish a comparison.

FIG. 434. WEST HALF OF CABLEWAY, LOCK AND DAM NO. 2. Showing Leads of Lines when Load is in Center of Span.

CLOSURE.

By R. D. Seymour, Mem. W. S. E.

Mr. Baldwin says that the method of arranging the lines on the cableway as described in the paper under discussion is not a new one, but he does not give us any data about where or when it was used previously. So many combinations of lines have been used that probably the method described is not new, but I believe this application of it to cableway construction is the first time it has ever proved successful.

I also think the statement made that this idea was invented by Mr. Spencer Miller is misleading. The patent used in the logging operations may have been invented by Mr. Miller, but it has no relation to cableways and no attempt has been made to use it on one. The method of arranging the lines shown in the cut is very different from the arrangement used in the machine under discussion and would prove a failure in practice, which is undoubtedly the reason it has never been used in cableway work. When the cableways were first introduced on the Drainage Canal an idea somewhat similar to the one used in St. Paul was worked up by Mr. C. H. Locher, but no attempt was made to demonstrate its utility in any practical way, nor was any patent taken out on it. The logging machines mentioned are not cableways and should not be described as such. The work done with them is of a different kind from anything I have ever seen done with a cableway, and the combinations of lines used on these machines are as old as the history of wire rope.

Mr. Baldwin should not object to the use of the "winch shaped drum" in this machine, as his company has used this style of drum on every cableway it has constructed where the span was over 500 ft. These winch shaped drums have been used regardless of the protests of the men who had to pay for the repairs, and of the wire rope manufacturers who have tried to make a rope that would stand the abuse and give good service under the conditions imposed by the builders of the engines. The use of these drums was necessary in this case for the reasons which will be given later.

The objection raised to the "swivel joint" mentioned may possibly be well taken, but it is hardly right to object to a thing that has not had a chance to show what its effect on the life of the rope will be. The use of a joint of this kind under the conditions described is an entirely new proposition and nothing but hard service can demonstrate whether it will have to be changed or not. This swivel is susceptible of several modifications, and if in service it is shown that any damage to the rope is caused by it I believe that it can be changed so that the wear will be reduced to a minimum and will be very slight when compared to that caused by fall rope carriers.

The Government officer in charge of the work at Lock and Dam No. 2 had had some experience with cableways and with fall

rope carriers. He wanted the best machine that could be built to do his work, and when the new system was offered was willing to give it a fair trial, provided the machine was so built that it could be changed to the fall rope carrier system if found necessary. This is the reason why the carriage and fall blocks, also the engine mentioned, were used, and why the Lidgerwood style of tower construction was followed. This condition in the contract was a serious handicap in the installation of the new system, and all the faults that can be found with the finished machine can be attributed to the use of parts of the older system.

The system used in this machine is what is known as the Laurent system, and the vital points of same are covered by Patent No. 653,698, which was issued to Louis E. Laurent, April 2, 1898.

The point made by Mr. Baldwin in closing his discussion about the improvements that have been made in fall rope carriers is well made, as the construction of the carrier itself is stronger and better designed to give longer service than those previously used; but that has nothing to do with the point made in the paper under discussion, which was that fall rope carriers of any kind largely increase the cost of maintenance and under all of the conditions for which cableways are designed are a very objectionable feature. This excessive cost of maintenance has been a bar to the introduction of cableways in many cases where they could have been used economically, and it is expected that the machine under discussion will prove that this item of expense can be largely reduced. This machine will have to handle about 100,000 tons of material, and an exact record will be kept of the work done and it will not be as "difficult to establish a comparison" as Mr. Baldwin seems to think.

XLV.

CONCRETE FACING ON A SANDSTONE BLUFF AT ST. PAUL, MINN.

ONWARD BATES, Mem. W. S. E.

Read 7th September, 1898.

The line of the Chicago, Milwaukee & St. Paul Railway Company in the city of St. Paul, beginning at the crossing of Chestnut street, extends with an ascending grade along the face of a bluff. This bluff is of a character common to the Mississippi River bluffs in that vicinity, and is composed of soft sandstone capped with an irregularly broken ledge of friable limestone, above which lie mixed together loose sand, gravel and boulders. This sandstone disintegrates readily, and is so soft that it wears away rapidly under the influence of the weather. The detritus from the bluff has frequently to be removed or it would cover the railway tracks, and the wearing away of the sandstone leaves the limestone ledge and the boulders which lie above it in a precarious condition, threatening the safety of trains on the tracks below. From time to time it has been necessary to build masonry walls on the face of this bluff for the protection of the railway tracks. The photographs submitted with this paper show such masonry walls.

In the summer of 1897 it was decided to protect an additional stretch of the bluff, and the writer concluded to use a concrete facing instead of cut stone masonry, for the reasons which follow.

He assumed that the stability of the sandstone would be secured if it was protected from the rain and frost, and that a facing of concrete or brickwork would furnish protection equal to that of cut stone masonry, at a saving in cost. He had a precedent for this in similar work that he had put in at Fort Snelling to support some dangerous projections of rock under similar conditions. At Fort Snelling the danger seemed imminent and the overhanging rock was supported by brick buttresses or pilasters, and the adjacent bluff was covered with brickwork to shed the water from it. The Fort Snelling work had been exposed for three years and had served its purpose without signs of deterioration to the brickwork. At St. Paul he concluded that it would not be wise to make a smooth face to the bluff, because it would cost less to support the projecting limestone with pilasters than to remove it. If the projecting stone had been removed it would have resulted in loosening the adjacent stone and the excavation would have extended beyond the railway company's right of way into valuable city property.

A description of the work will be better understood by reference to the illustration.

In Fig. 436, the tracks shown in the foreground are those of the Chicago, St. Paul, Minneapolis & Omaha Railway Company, which are on the level bottom land at the foot of the bluff. The double track line of the Chicago, Milwaukee & St. Paul Railway Company lies on the bench which is supported by a retaining wall of stone masonry. At the left is shown a protecting wall of cut stone masonry. In the background is shown the work under discussion at an early stage of its progress.

The loose material was removed from the face of the bluff, and the next operation was to build brick pilasters under the projecting limestone. Three of these pilasters were built, the one nearest to the left is 6 ft. 0 in. wide and 4 ft. 3 in. thick; the second one is 12 ft. 0 in. wide and 4 ft. 9 in. thick; and the third one is 6 ft. 0 in. wide and 4 ft. 6 in. thick. The dimensions of these pilasters give an indication of the sizes of the stone projections which they support. While the work was in progress, a heavy section of limestone, located some 200 ft. from the left, tumbled down and temporarily obstructed the railway track, but its unstable condition was known and there was nothing in the way to be injured by its fall. By reference to Fig. 437, it will be seen that projecting bricks are built into the pilasters near their inner corners, which bind the pilasters and the concrete facing together.

The foundation for pilasters and concrete facing is in the sandstone, 4 ft. below the base of rail of the railway tracks, the footing course being 2 ft. deep and 10 inches wider than the wall above it.

The supporting frames for the concrete were put on in the following manner:

Bolts were put into the sandstone at distances apart of 8 ft., horizontally and vertically. With special augers holes were bored into the sandstone from 4 ft. to 5 ft. deep, inclining downwards so that the bolts would stand perpendicular to the face. The bolts were $\frac{3}{4}$ in. in diameter and were placed in the holes with nuts on the lower ends, the holes being then filled around the bolts with mortar, a process easy of accomplishment on account of the downward inclination of the holes. The bolts projected about 18 in. beyond the face of the sandstone with their ends terminating in cast iron nuts of cruciform section, and with the threads in the nuts long enough to engage a second section of $\frac{3}{4}$ in. bolt. This second section of bolt held the uprights in place. The uprights consisted each of two planks 2x8 in section with the bolt passing between them. The planking supporting the concrete was placed against the inner edges of the uprights. This framework was built up in horizontal sections, the uprights and planking used at the bottom being afterwards used again higher up on the wall. To remove the planking it was only necessary to unscrew the nuts which held the uprights, and when

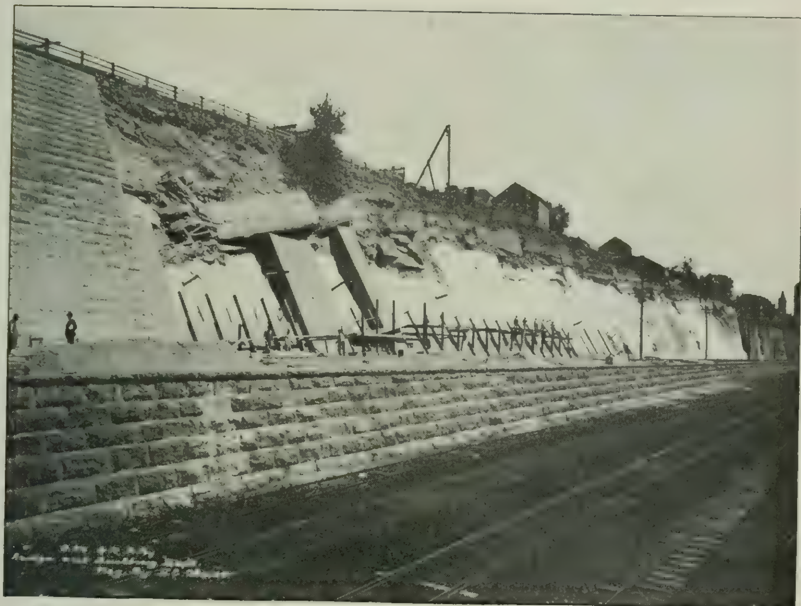


Fig. 436. Face of Bluff with Brick Pilasters in Position.

Fig. 437. Broken Limestone Ledge Supported by Brick Pilaster.

the concrete wall was exposed, the short ends of bolts were screwed out, leaving the wall securely bolted to the sandstone, and the bolt holes were then filled with mortar. It was not considered necessary that the concrete should be bolted to the sandstone, but the bolts were required to secure the concrete frames, and the easiest way to dispose of them was to uncouple and remove the short ends, and such value as they give in holding the concrete in place is gained without extra cost.

The method of bolting the frames to the bluff is shown in Fig. 438.

The work had to be carried on in the limited space between the railway tracks and the bluff. The sand for concrete was brought on cars and deposited outside of the tracks on the edge of the bench supporting them, as shown in Fig. 436. The broken stone was brought by team to the top of the bluff and dumped through a chute built against the stone wall, as shown in Fig. 437. The mixed concrete was deposited by wheelbarrows, using for the lower courses an inclined runway and later the wheelbarrows were hoisted by a derrick located on the bluff. This derrick is shown in Fig. 436. It was operated by steam, the engine being placed at the foot of the wall.

When the concrete wall was built up to the limestone ledge, all loose stone and dirt was removed, and the vacant spaces carefully filled with concrete. In some places where it was difficult to place the concrete, brickwork was used. Fig. 439 shows some of this brickwork located between the projecting pieces of limestone.

The concrete was continued from the top of the limestone ledge to the top of the bluff, and special care was taken to make the work tight at the top so that water would not get in behind the concrete.

The four engravings show the conditions in different stages and after the completion of the work, the finished work being represented by Fig. 439. No attempt was made to put in the concrete with a uniform slope, it being fitted against the formation of the bluff. This is plainly shown in Fig. 439, where a considerable depression or pocket appears at the left of the telegraph pole. The slope of the first pilaster is 11¼ in. in 24 in.; of the second pilaster 12½ in. in 24 in.; of the third pilaster 13½ in. in 24 in., while the slope of the concrete varies from 12½ in. to 17 in. in 24 in., so that the general average slope of the work is approximately 1 horizontal to 2 vertical.

The brickwork was laid up with Milwaukee cement mortar except the exposed bricks, which were laid in Portland cement mortar. The concrete was made with 4 parts of Milwaukee cement to 6 parts of sand and 15 parts of broken stone; and was faced with 1½ inches of Portland cement mortar, composed of 1 of cement to 2 of sand. The mortar facing was placed at the same time as the concrete, so that it set with it, making a perfect union. West-

ern Portland cement made at Yankton, S. D., was used except for a small portion of the work, for which Empire Portland cement was supplied to make up a shortage of the Western.

The work was expensive on account of the limited space for working between the railway and the bluff, and the expensive nature of the concrete frames; but the cost per yard was less than if cut stone masonry had been used, and the quantity of material in the wall was also less. If the work were to be done over again, the only change the writer would recommend is that concrete should be substituted for brick in the pilasters, as being equal in quality and costing less than the brick work. The work has been in place for a year and no faults appear in it. For similar work the thickness of the concrete facing, may in many cases be safely reduced. On sandstone of this class all that is required is that it should be protected from the weather, but care must be taken to prevent the water from getting in between the concrete and the sandstone. In the work described, the walls are thick enough to support the broken limestone, boulders and earth, as well as to prevent the sandstone from wearing away.

The following figures are taken from the records of the work:

DIMENSIONS.

Height of sandstone	30 ft.
Height of limestone ledge	12 ft.
Height of layer of sand, gravel and boulders	14 ft.
Height of wall above footing	56 ft.
Depth of footing	2 ft.
Length of wall	256 ft. 6 in.
Average thickness of brick pilasters	4 ft. 6 in.
Average thickness of concrete footing	3 ft. 3 in.
Average thickness of concrete facing below ledge	2 ft. 5 in.
Average thickness of concrete facing above ledge	3 ft. 2 in.

QUANTITIES.

Brick pilasters	141.5 cu. yds.	
Brick face wall	26.0 cu. yds.	
		167.5 cu. yds.
Concrete footing	61.2 cu. yds.	
Concrete face wall below limestone ledge	1038.5 cu. yds.	
Concrete face wall above limestone ledge	195.0 cu. yds.	
		1294.7 cu. yds.
Total brickwork and concrete		1462.2 cu. yds.

COST.

Brickwork, labor \$2.09; material, \$2.91; total	\$ 5.00 per cu. yd.
Concrete, " \$1.83 " \$2.32 "	4.15 per cu. yd.
Brickwork and concrete (average)	4.64 per cu. yd.
Brickwork and concrete (256′ 6″) wall	26.46 per lin. ft.
Total cost of wall " "	\$6,787.36.

FIG. 438. METHOD OF BUILDING FRAMES TO SUPPORT CONCRETE.

FIG. 439. BLUFF PROTECTED BY CONCRETE FACING.

Above cost covers all labor and material expended in preparing the bluff to receive the wall; building the wall complete and removing all debris and waste material; and rebuilding fence after completion of work. It also includes engineering expense, but does not include freight charges on cement, sand and brick.

The work was done by the Bridge and Building Department of the Chicago, Milwaukee & St. Paul Railway Company, Mr. F. E. Rice being the engineer in direct charge.

DISCUSSION.

Mr. Wisner: Was there any difficulty in making the facing water-tight at the top?

Mr. Bates: Well, we think it is reasonably water-tight; we took special care to pack the concrete and to give it a slope so that the water would run away from it.

Mr. Wisner: What is the minimum thickness of the concrete facing?

Mr. Bates: I have not the minimum thickness, but it is not much less than the average thickness, which is 2 feet 5 inches. The thickness is determined to as great an extent by what the concrete has to support as by the protection of the sandstone itself.

Mr. Wisner: How was the concrete put into place?

Mr. Bates: Up to say fifteen feet it was carried in wheel-barrows that were run up an inclined runway; above that the wheel-barrows were hoisted by derricks, the derricks being set on the top of the bluff.

Mr. Wisner: Is the concrete put in layers and tamped?

Mr. Bates: Put in layers, yes. We did not carry the work on continuously, we stopped every night.

A Member: Is there no danger from the drainage of the sandstone itself? Is there water behind the concrete?

Mr. Bates: No, I do not think any water gets into the sandstone.

XLVI.

THE FOUNDATIONS FOR THE U. S. GOVERNMENT POST-OFFICE AND CUSTOM HOUSE BUILDING AT CHICAGO.

By WILLIAM SOOY SMITH, Mem. W. S. E.*

Read 28th September, 1898.

Before beginning the description of the foundations of the Chicago Post Office building your attention is invited to a statement of the kinds of materials met with in constructing them. This will facilitate a clear understanding of the merits of the plans devised, the reasons for their adoption and the methods employed in the execution of the work.

The City of Chicago stands upon a flat plane. The materials underlying it are as shown on accompanying sections. (Fig. 440.)

Commencing at the surface where this has not been disturbed there is about one foot of black soil. Below this there is a stratum of rather fine sand from six to eight feet in thickness near the lake, and growing thinner westwardly until it disappears. Under this sand where it is found, and beneath the black soil where the sand does not occur, there is a stratum of stiff, moderately hard clay, from three to eight or ten feet thick. And from the bottom of this hard clay to a depth of from forty to sixty feet below city datum (low water lake level), the material is very soft clay, saturated with water, with now and then a thin stratum of firmer clay, usually not more than two or three feet in thickness. At the bottom of this very soft clay, at a depth of from forty to sixty feet below city datum, the clay becomes hard and mixed with a small and gradually increasing percentage of sand and gravel, changing into a genuine hardpan within the first three or four feet. This hardpan is so hard that it cannot be penetrated with the common wood auger usually employed in making borings; and when it is desirable to go deeper with a test hole, resort must be had to a drill.

It is from six to thirty feet in thickness, and rests upon a solid bed of limestone lying at a depth below city datum of from sixty to ninety feet.

In making excavations for the foundations of large buildings in Chicago they are generally carried down from ten to fifteen feet below curb grade. This means the removal of the soil and sand at the surface and a portion of the hard clay below.

From this description of the materials underlying the site of the city, it is hoped that a clear understanding may be gained of the circumstances which exist and the conditions which must be considered and complied with in designing the foundations of heavy buildings in Chicago.

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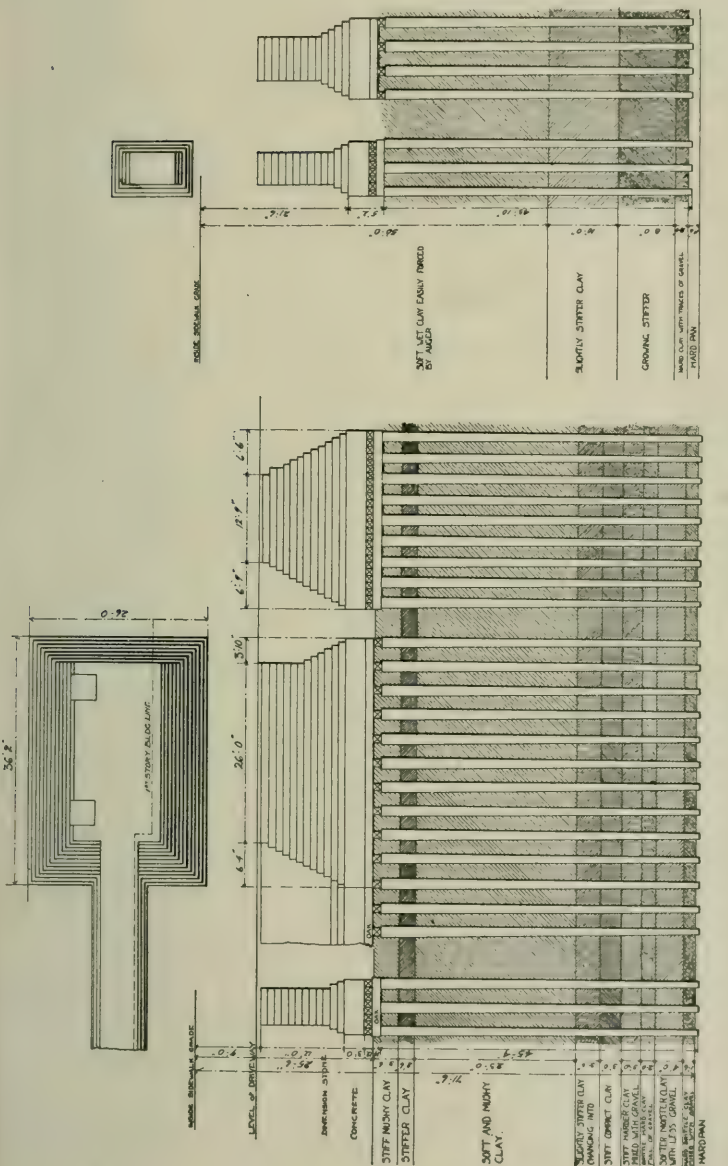
*Engineer in charge of Foundations for U. S. Government Post Office and Custom House Building, Chicago.



DETAILS OF FOUNDATION PIERS

Fig. 440.

Experiments repeatedly and carefully made by loading the soft clay found at the bottom of the proposed basement floors show that it begins to yield under loads varying from three to four thousand pounds per square foot. But if these loads remain, the settlements which take place will appear to cease during the time commonly occupied by the experiments. If the loads are increased much beyond four thousand pounds, the settlements do not cease, but seem to go on continuously, though at a gradually diminishing rate. And in many instances in which buildings have been erected on foundations covering such areas as to make the loads carried by the soil well within the limit of 4,000 pounds per square foot, these buildings have within a few years from their completion settled and cracked badly. These settlements have been so slow that they could only have been detected and accurately measured by levels carefully taken at long intervals. Such levels taken on the Board of Trade Building during six years showed a total maximum settlement of 16½ inches and minimum of 8 inches, which caused it to crack so badly that parts of it had to be taken down. The average settlement was 12¼ inches in six years, 2 1-24 inches in one year, or only about ½ of an inch per month. From which it must appear that those who built in accordance with the teachings of the experiments made were pardonable for the costly errors that resulted from ignorance of this insidious peculiarity of the soil which no experiment had revealed.

The simple fact is that there is a gradual settlement that goes on during long periods under loads less than those which the soil will sustain temporarily. This probably results from the gradual squeezing out of the water in the clay through its infinitesimal interstices by the superincumbent loads. As the time during which this movement of the water takes place increases, the velocity and resistance from friction diminish, and as the water disappears the clay is more easily compressed, and hence this slow settlement. In confirmation of this theory it is found, where excavations are made of soil that has been long loaded, it is found compressed and partially dried to a considerable depth below the loads. Nothing but very close and accurate observations and measurements made through a term of years can determine just what is the maximum safe load that this soil will sustain permanently; and as there is considerable variation in the character of the materials at different places, it would seem very difficult if not impossible to fix upon any load that could be considered safe, which would not be so small as to be of no use in planning foundations.

In the case of the foundation of our Government Post Office and Custom House Building, which are under consideration, all the controlling circumstances seemed to lead to the designs that were adopted, and which have now been carried out to completion without a single serious difficulty or accident, by the McArthur Bros. Co., contractors.

The building is to be monumental in its character. The appro-

priation made by the Government for its construction is munificent, amply providing for building the magnificent edifice that it will be, after the very best methods, especially such as will absolutely insure its greatest durability. The plans by Mr. Henry Ives Cobb, architect, seem models of correct design, adapting each part of the building to its purposes and providing amply for all requirements with a minimum quantity of materials.

The weight of the building will be very great, amounting to about 150,000 tons. The several methods of construction of the foundations studied and compared were:

1st, Masonry on platforms of steel beams and concrete.

2d, Wells sunk to hard pan and filled with concrete or rubble masonry.

3d, Piles driven to hard pan, wooden grillage concrete and masonry.

The first method was rejected because unsafe and too expensive. The second method, though deemed perfectly safe and reliable, was from careful estimates found to be unnecessarily expensive for this site. The third method, with piles, timber platforms, concrete and masonry, was adopted as being free from any danger of settlement and less expensive than either the first or second methods.

The piles are so many posts resting on an unyielding bottom and sustained from lateral flexure by the pressure of the surrounding materials, thus affording positive support for the loads they carry and transmitting them directly to hard bottom.

The maximum load to be carried by a pile was arrived at by reference to a great many examples of old structures on pile foundations in similar materials, notably some of the London bridges across the Thames and bridges across the Seine in Paris, in which the piles are loaded to sixty tons each and even to one hundred tons in one of the latter. Also by calculating the sustaining power of piles of the same kind used in the foundations of the Public Library and other very heavy buildings in Chicago. During the construction of the foundation for the Public Library Building I loaded one of the piles with all the pig iron that could be stacked on it conveniently (fifty-three tons), and had this load left on it for weeks, without producing any settlement, after the first subsidence due to the elasticity of the pile. The application of Trautwine's formula to the piles in the foundation of the Post Office building since they have been driven, shows the load adopted of thirty tons (each) to be perfectly safe.

Preliminary borings made for the purpose of determining the quality of soil underlying the site of proposed building, resulted as follows: (See also Fig. 440.) After boring through the filled material and sandy soil for about twelve feet below surface of street, a layer of hard brittle clay, about three feet thick, was struck. Below this to a depth of from 55 to 60 feet below street level the clay was very soft, with spots of stiffer clay, and traces of

gravel in places, but nowhere firm enough to sustain any considerable load. From the depth of 55 to 60 feet the material grew harder gradually, with more gravel, until at the depth of from 69½ feet to 71½ feet below the street level, hard pan was struck, into which it was impossible to bore with a common wood augur.

From the borings it was determined that the length of piles in the foundations, to be cut off 26½ feet below street level, would be from 43 to 45 feet, provided they were driven to hard pan, so the plans were made for 50 foot piles, to allow for slight irregularities in the top surface of the hard pan and the sawing off.

Excavations to a depth of 30 feet below street grade verified these borings to that depth. The material is a blue, plastic clay, weighing 136 pounds per cubic foot. It contains some pockets of coarse sand and a few boulders of various sizes.

The piles driven with square ends without sharpening are cut off 26½ feet below street level or 12½ feet below low water level of the lake. The thickness of the caps 14 inches added to that of the platform resting on them 12 inches thick, brings the top of the platform 2 feet 2 inches above the tops of the piles and 10 feet 4 inches below lake surface at low water, insuring perpetual immersion of the highest timbers in the foundation and hence everlasting durability.

The foundations would have cost considerably less if the piles had been cut off eight feet higher and the timbers would still have been 2 feet 4 inches below lake surface and so perpetually wet. But in view of the possible disturbance of the foundations by the construction of subways in the streets, or by any other deep excavations in the immediate neighborhood made for any purpose, it was deemed best to cut the piles off at the lower level determined upon.

There are 5087 piles, including 59 under the foundations for subtreasury vaults. (See general plan of south half of foundations Fig. 441.) They are of Norway pine, not less than 16 inches in diameter at the butt, and 10 inches at the point. They were driven by a steam hammer, the falling part of which weighs 4700 lbs. and drops 42 inches. The hammer frame and engine weigh 4,500 lbs. They were driven until it required from 6 to 8 blows of the hammer to drive the pile one inch.

PENETRATION.

Observations taken on 30 piles chosen at random resulted as follows:

Average No. of blows to drive pile from		0 to 10	ft.	16	blows.
"	"	10 to 20	"	53	"
"	"	20 to 30	"	102	"
"	"	30 to 40	"	212	"
"	"	40 to 45	"	199	"
"	"	45 to $46\frac{1}{10}$	"	106	"
Average total No. of blows,				688	

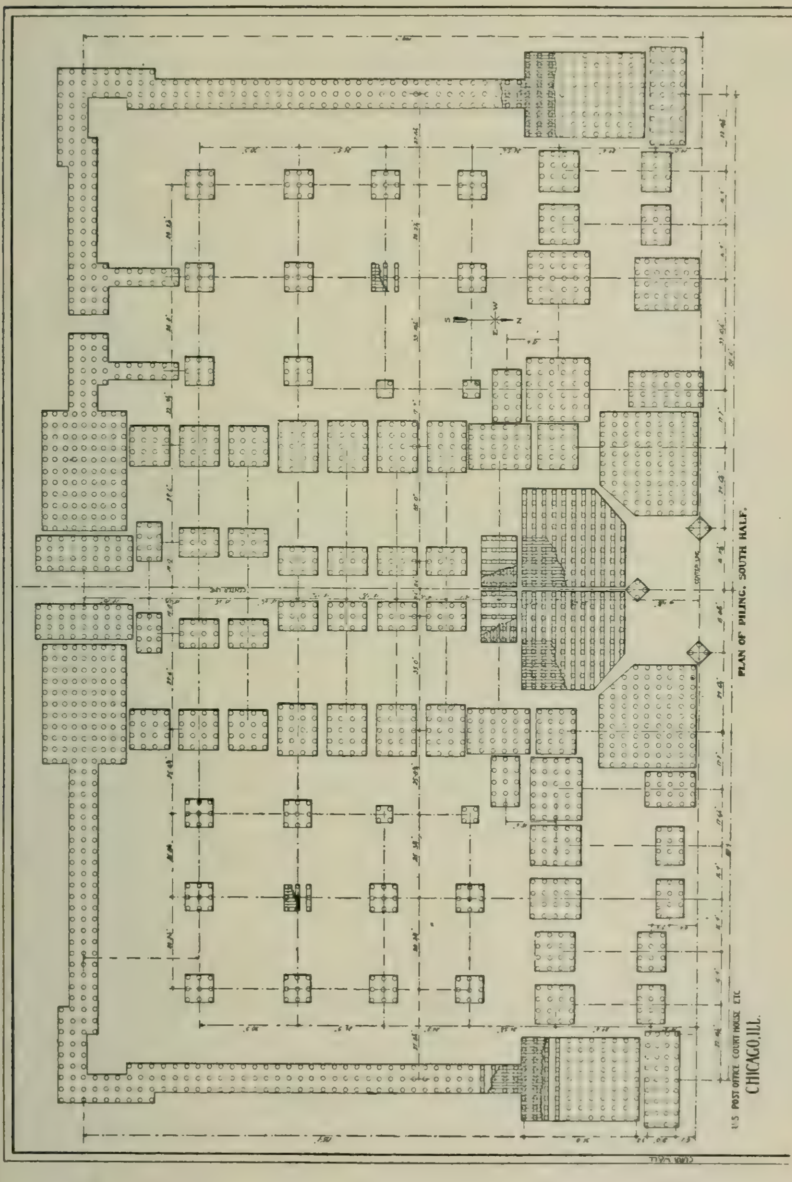

PLAN OF PILING, SOUTH HALF.
U S POST OFFICE COURT HOUSE ETC
CHICAGO, ILL.

FIG. 441.

Average penetration per 10 blows at	30	ft. deep	$8\frac{1}{2}$ inches.
" "	40	ft. "	$4\frac{1}{8}$ "
" "	45	ft. "	$2\frac{5}{8}$ "
" "	$46\frac{1}{10}$	ft. "	$1\frac{3}{4}$ "

This gives an average of about 6 blows per last inch of penetration.

Taking five blows as the least number per last inch, and using Trautwine's formula.

$$\text{Extreme load in tons} = \frac{\left\{\begin{matrix}\text{Cube root of}\\ \text{fall in feet.}\end{matrix}\right\} \times \left\{\begin{matrix}\text{Wt. of hammer}\\ \text{in pounds.}\end{matrix}\right\} \times .023}{\text{Last sinking in inches} + 1.}$$

We find that the extreme load that one pile will sustain is 136.75 tons. This, without any allowance for the effect of the insistent load of four thousand five hundred pounds resting on the pile while it is driven, allows a factor of safety of about four and one half, as the piles will sustain about thirty tons each.

METHOD.

A space 144 feet square in the middle of the lot was excavated to a depth of $3\frac{1}{2}$ feet below cut off grade, and the piles within this space, 1340 in number, were driven by drivers running on cribbing on the bottom of the excavation, and required no follower. The remainder of the lot was excavated in trenches or pits, and the drivers ran on top, the cribbing resting on the surface of the ground or the tops of piles partially driven. The piles were "followed" from the surface to the bottom of the excavations, and in some cases, where the excavations were not completed, the piles were followed several feet into the earth.

LENGTH OF PILES.

The length of piles after being cut off, varied from $42\frac{1}{2}$ to 47 feet, and agreed well with the borings. The greatest variation was at the S. E. corner of lot, where the piles were $2\frac{1}{2}$ feet shorter than the borings would indicate, and where the driving was extremely hard for the last few feet. In the center of the lot the piles were two feet longer than the borings indicated, but as none of these were made in that vicinity, this could not be called a variation.

DISPLACEMENT.

The displacement of material by the piles was found by adding the amount of material that would have to be removed to leave the lot at "finished grade," and the amount of all material (other than piles) put into the foundations, and subtracting the sum from the amount of material actually removed from the ground.

Amount to be removed to leave lot at finished grade	8242 cub. yds.
Amount of material (other than piles) in foundations	19381 "
	27623 "

Amount of material actually removed 35230 cub. yds.
Displacement of material by piles 7607 "
or 40 cu. ft. for each of 5087 piles, corresponding very nearly with the volume of the pile.

This displacement took effect in the direction of the least resistance, generally raising the earth in the bottom of the trenches and pits from two to five feet.

Piles already driven were heaved or lifted by driving other piles in the immediate vicinity. This heaving amounted in some cases to 4 or 5 inches. Levels taken on test piles showed results as below; observations taken Sept. 21st, 1897. (See Fig. 442.)

Pile No.	Elevation when piles were driven as per plan.	Elevation when piles were all driven in piers.	Amount of heaving.
3	11.448	11.081	0.367 ft.
4	10.723	10.689	0.034 '
5	10.619	10.581	0.038 "
6	11.088	10.898	0.190 "
7	10.943	10.826	0.117 "
8	10.448	10.419	0.029 "

This shows a maximum heaving of 4⅜ in. in pile No. 3, but it is probable that it was raised some by the driving of the piles southeast of it before the levels were taken.

Piles which stood four rows or 12 feet back from the driving were heaved from ¼ in. to ½ in. and those 18 or 20 feet back were not affected perceptibly. These observations were taken where the driving was very heavy, that is, the whole area was filled with piles at distances of 3 ft. by 3 ft. 6 in. Where the piles were not so numerous, as in trenches containing two or three rows, the effect was not so great, as piles 6 or 8 feet back were not heaved.

As a test to determine whether the heaving made the piles any less secure for a foundation, the hammer was placed on one which had been raised and it was struck 30 blows with the following result:

1st 20 blows 5 inches penetration or 4 blows per inch.
Last 10 blows 1¼ in. " " 8 " " "

Taking ¼ in. as the penetration for last blow, Trautwine's formula gives an extreme load of 131.28 tons, which shows that the pile is practically as safe as one requiring 5 blows for last inch.

Piles which were driven partially down, and allowed to stand for several days before following (as those on which the cribbing was placed for supporting driver) were found to be much harder to drive than those which were driven clear down at once. This may have been because the surrounding piles compacted the material below it, or because of the friction of the earth settling around it as it stood.

The follower used in driving the piles consisted of a 10 in. wrought iron pipe about 15 feet long, into which was driven a tight fitting cylinder of hard maple. On the lower end was

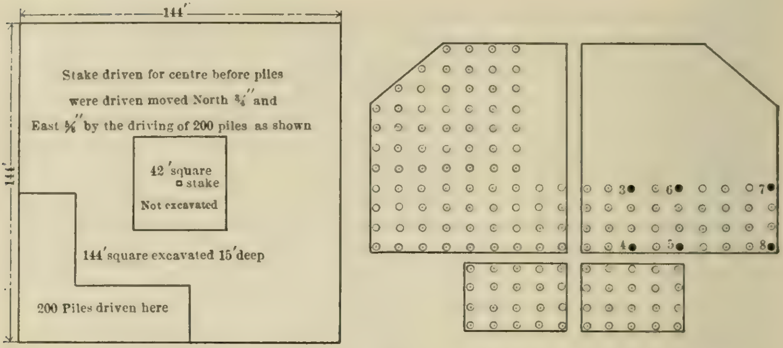


FIG. 442.

bolted a cast iron hood, in the under side of which was a socket to fit over the head of the pile and on the upper side one to receive the 10 in. pipe. On the upper end of the follower was shrunk a 1x6 in. iron ring, forming a socket in which was placed a hard maple plug about 12 in. long. This plug was the only part that was injured by the force of the blow, and consequently the only part that had to be renewed.

Along one side of the follower was a one inch iron pipe, which screwed into a hole running down to the under side of the hood. This was originally intended to admit air under the follower to get rid of the "suction" when pulling the follower out, but it was afterward connected to the boiler by means of a rubber hose, and the steam pressure used to assist in pulling the follower.

Plate—Another improvement in the pile driver was a steel plate 1 1/2 inches thick and of sufficient diameter to fit in the hammer. This was placed on top of the pile, and was a great protection against splitting or brooming. Later on a new casting was made for the lower part of the hammer and this contained a slotted "recess" to hold the steel plate in the proper position, so that it was not necessary to handle it when moving from pile to pile.

Timber Capping—After the piles were sawed off at the proper grade, white oak caps 14x14 in. were placed on top of them, crosswise of the trenches, and bolted to the piles by means of one inch wrought iron driftbolts, 24 inches long, one in each end of every timber. On top of these caps was placed a solid platform of 12 in. x12 in. white oak timbers, the outside timbers of each platform being bolted to each cap timber by a drift bolt 20 inches long. The caps and platform timbers were all planed and sized to the dimensions given, to insure good bearings.

Concrete—On top of the platforms was placed a layer of concrete 3 feet thick, composed of one part Portland cement, two parts sand and five parts crushed stone.

The cement was required to show a tensile strength of 250 pounds in 7 days, mixed in a proportion of 1 cement to 2 sand. The concrete was all mixed by hand and the amount put in va-

ried from two to three cubic yards per man per day of 10 hours, depending on the distance of wheeling material and concrete.

The cement and sand were first mixed dry, then water was added, and the stone was spread on top. The whole mass was then turned by shovels two or three times, and then shoveled into wheelbarrows or directly into the piers, where it was spread in layers about 6 inches thick, and thoroughly tamped.

Test holes about two feet square and two feet deep were sunk in two piers to determine quality of concrete. The concrete was taken out in chunks as far as possible, and the sides of one hole were brushed with a steel brush and the other was washed with water from a hose. No voids were found, and the concrete was very hard, considering the short time it had been in place. There are 5,122 cubic yards of concrete. The cement used at the beginning of the work was Alpha, but later it became impossible to obtain the Alpha and Atlas was substituted.

Masonry—The masonry was built of Joliet and Lemont limestone.

The stone used varied in thickness from 10 inches to 30 inches, and was dressed so as to make the joints not more than one inch. The outsides of the piers and walls were left rough and in some cases extended several inches beyond the neat size of piers.

The mortar used consisted of one part cement to two parts sand, the cement requiring the same test as for concrete.

The stone was all laid by derricks. In the central part was a system of four boom derricks, located on the axes of the building, 85 feet in each direction from the center. These derricks had 80 feet masts and 75 ft. booms, and laid all the stone for foundations for dome and the greater part of the lines of piers running out under the walls of the main wings of the building. The corners and outside walls were laid by four traveling derricks. Each derrick is supported on a turntable, revolving on a circular track of railroad iron. This track is on a platform, which is moved on rollers in the same manner as a pile-driver. The engine is placed on the rear end, and balances the weight handled. This derrick will lift several tons, and is much more convenient than a guy derrick, as it can be moved so readily from place to place. On account of delay caused by lack of material, it was difficult to estimate the amount of work that one derrick can do, but from 1,000 to 1,500 cubic feet is a fair day's work (8 hours) when the material is on hand ready to put in without any dressing. This requires a force of 4 masons, 4 laborers, 2 hookers, 1 engineer and 1 fireman.

The total quantities of materials handled and entering into the construction of the foundations and the unit prices were:

	Quantities.	Unit Prices.
Excavations, basement............	22,267 cu. yds.	$ 0.33
Excavations, trenches............	54,294 cu. yds.	0.34
Piles (50 feet long)...............	5,087 piles.	11.70

	Quantities.	Unit Prices.
Timber capping	796,352 feet B. M.	27.80
Concrete	5,122 cu. yds.	5.45
Dimension stone	284,144 cu. feet.	0.24
Rubble masonry	31,327 cu. feet.	0.16
Total contract price		$209,821.94

The contract time for completion of the work was April 15th, 1898, and it was understood that all the dimension stone required could be so promptly furnished that the masonry could be completed before that date. In order that this might be done it was necessary that the stone should nearly all be quarried during the summer and early fall of 1897, so that it might be sufficiently seasoned to prevent cracking by freezing and thawing during the following winter. It turned out that the stone ran short during the winter, and a large portion of it had to be quarried during the spring and summer of 1898. Strikes of the quarrymen occurred and the delivery of the stone was so retarded that the masonry could not be completed until September 26, 1898.

The character and capacity of the plant provided by the contractors for doing the work were such as to make its accomplishment easy and certain within contract time, if the materials had been delivered as contemplated, and the plant handled with skill and energy. The rapidity with which pile foundations can be put in under the circumstances which exist in Chicago, is a strong consideration in their favor in this city of hurry and push.

A careful estimate of the cost of the foundations if wells. filled with concrete, had been employed showed that it would have exceeded the contract price of the pile foundations by at least one hundred thousand dollars, and the excess of the estimate for the steel and concrete platform plan over the actual cost of the pile foundations would have been at least twenty-five thousand dollars.

None of the circumstances pointing to the use of either of the other two plans existed in this case, and there was, therefore, no room for doubt as to which plan should be adopted.

The reasoning herein presented has been fully confirmed by all the facts developed during the progress of the work, and we feel that the pride and confidence that we have in this typical example of pile foundations for this locality are fully justified.

XLVII.

TRACK ELEVATION OF THE CHICAGO & NORTHWESTERN RAILWAY.

By Louis H. Evans, Mem. W. S. E.*

Read October 5, 1898.

The Chicago & Northwestern Railway terminal in Chicago consists of three distinct entrances to the city: The Galena Division, from the west; the Wisconsin Division, from the northwest; and the Milwaukee Division, from the north; as shown on the map, Fig 443.

The Wisconsin and Milwaukee Divisions come together at Clybourn Junction, about 2½ miles from Wells Street Station on to a common right of way, one hundred feet wide, but will be two double track systems from there to one-half mile from the depot.

Besides the three systems above mentioned the road owns and operates a belt railway from North Evanston to the south branch of the Chicago River at 16th St., and a one-fourth interest in the Air Line which continues this belt line to a connection with the Illinois Central Ry. This belt line crosses every railway entering Chicago.

The Chicago terminal comprises 768 acres of land; $36\frac{73}{100}$ miles of double track railway used as running tracks, and $159\frac{69}{100}$ miles of track in yards for storage tracks, team tracks, etc.

With a terminal as extensive and valuable as this, the question of track elevation was a very serious one on its first appearance. In fact, the estimated cost of elevating the terminal to comply with the terms of the O'Neill ordinance was about $65,000,000, an estimate properly made, too, as it consisted of raising the terminal entire, buildings and all, sixteen feet and building a wall around it. Opposition to such a proposal was justly very strong; but when the city showed a disposition to compromise and write ordinances that were for part of the terminal at a time, thereby rendering the outlay for elevation each year within the reach of a prosperous railway, it was a different question, and in the investigation that followed it was discovered that this railway could pay for elevating its Galena Division from Sacramento Ave. to 40th St., both inclusive, and still remain solvent.

After considerable discussion, an ordinance was drawn by the city, February 18, 1895, to elevate the Galena Division as above defined, giving twenty-seven months in which to do the work; the distance to be elevated being about $1\frac{8}{10}$ miles, the right of way 100 feet wide, six subways to be built, five tracks to elevate, and

*Engineer of Track Elevation C. & N. W. Ry. Co.

FIG. 443. MAP OF CHICAGO TERMINAL OF C. & N. W. RY.

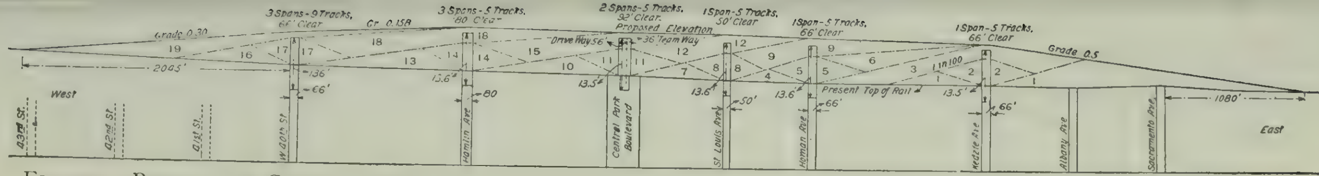


FIG. 444. PROFILE OF GALENA DIVISION ELEVATION FROM SACRAMENTO AVENUE TO 43D ST., SHOWING PROGRESS OF FILL.

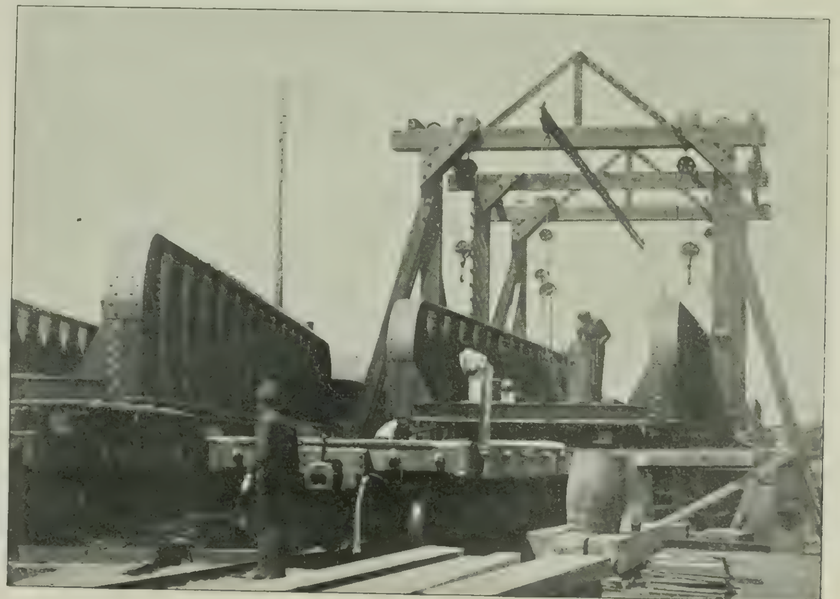


FIG. 445. DERRICK USED FOR ASSEMBLING BRIDGES.

considerable work at each end in changing yards to fit the condition incident to elevated tracks, see profile, Fig 444.

The plan of work accepted by this company was a new method, which consisted of assembling the manufactured girders and floors into complete bridges at a derrick, Fig. 445, at the end of section to be elevated, and moving the bridge thus assembled on special flat cars to the subway, where they were lifted free from the cars and landed on piles driven between tracks to temporarily support the bridge and traffic until stone abutments could be built. The method used on the Galena Division is shown in Fig. 446 (a), (b) and (c).

The completed bridge loaded on, Fig. 446 (c), two cars was a proper load, except as to its shape, the width being 14 ft. 8 in. made it appear very unstable when placed three or four feet above the car floor, which is nine feet wide and carried on a wheel base of only five feet. We never were able to throw a bridge off the cars, however, notwithstanding the fact that we had the cars (loaded with bridges) off the track several times. Our first bridge was moved one mile successfully and unloaded on to the piles in an hour, so we felt that the system of assembling the bridges at the end of the work, where we could arrange for and do field work, practically as cheap as shop work, was no mistake.

The five tracks on this section of the road required three bridges and two intermediate floors. To illustrate the time required to place the bridges and get the traffic over them, we will take Homan Ave., the second subway built: Two bridges were placed May 24, at eleven A. M., at Homan Ave., Fig. 447, the approaches were built during the afternoon, and a train of sand went over one of these bridges May 25, at seven A. M., and double track traffic went over these bridges May 25, at 12:30 P. M. The third bridge was placed May 25, 11:20 A. M., and the intermediate floor put in during the day of May 25, illustrating that the bridges could be placed and the approaches filled so that traffic could go over the elevation at a street in twenty-four hours. The bridges were not placed at the full elevation of ten feet at first, but were at about seven feet elevation and afterwards raised four feet more. The excavation of the street to the new grade and the foundations for the abutments could start at once, the work being entirely independent of the track raising after the bridges were placed. The two masonry abutments were built at this street from June 7th to the 13th; finally, the traffic was on the old grade May 24th, on the new grade on iron bridges May 25th, and on the new grade on iron bridges on stone abutments June 13th; in sixteen working days five tracks were permanently elevated eleven feet. This rate of progress was kept up until all the bridges were placed, which required until July 18. From May 11th, during this time 275,000 cu. yds. of sand were unloaded, 52,000 cu. yds. gravel, 7,300 cu. yds. of masonry in abut-

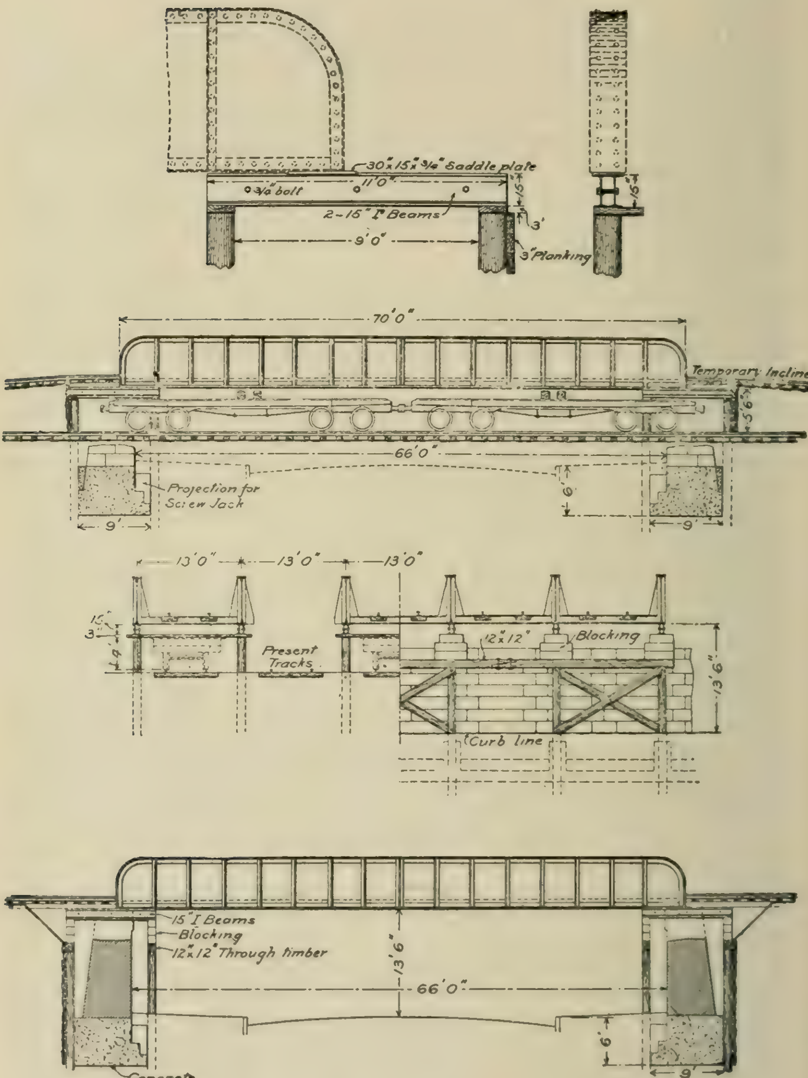


FIG. 446.

(a)—METHOD OF TEMPORARILY SUPPORTING SPANS, USED ON GALENA DIVISION.

(b)—COMPLETELY ASSEMBLED SPAN, ON CARS, READY TO BE LANDED ON TEMPORARY SUPPORTS.

(c)—CROSS-SECTION SHOWING ARRANGEMENT OF TRACKS DURING ELEVATION.

(d)—SPAN IN PLACE, SHOWING PILES, ABUTMENTS AND BACK WALL

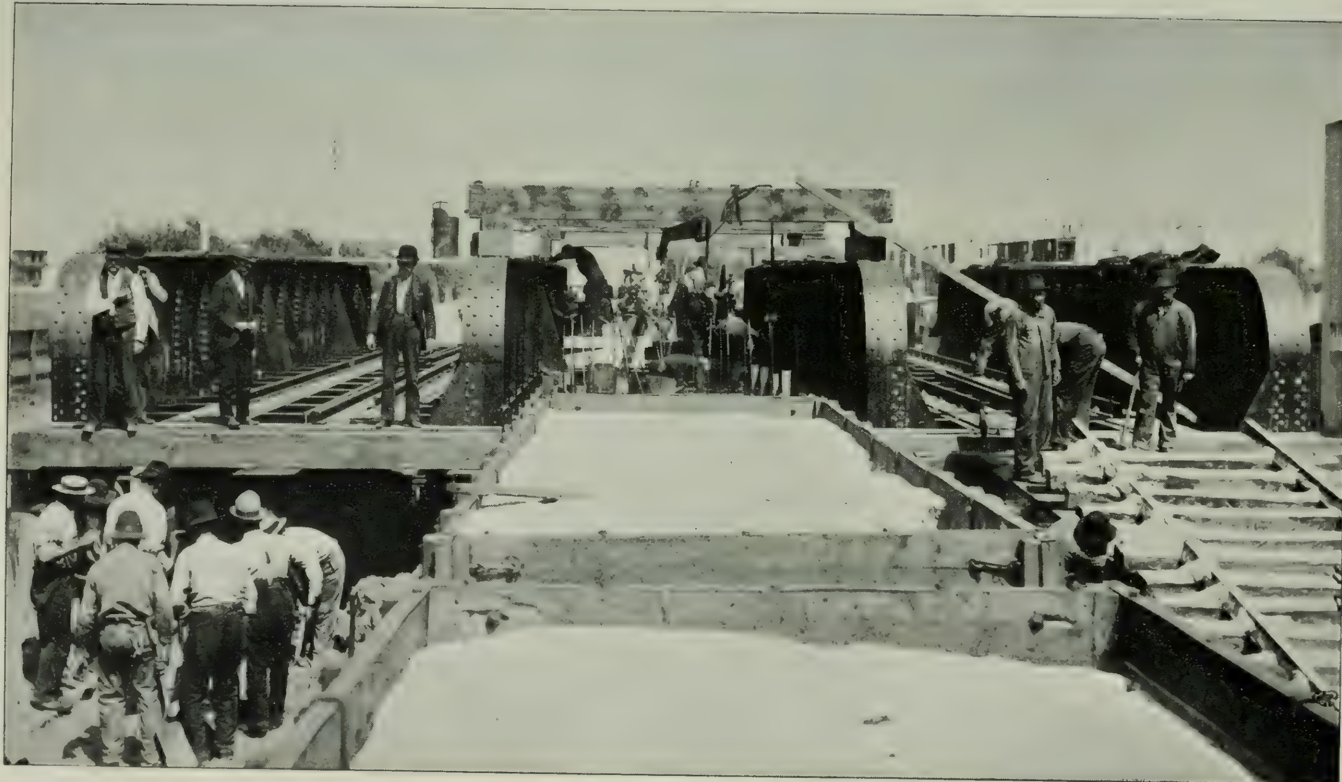


Fig. 447. Intermediate Floor Being put in Between two Bridges at Homan Ave., also Sand Filling for Approaches.

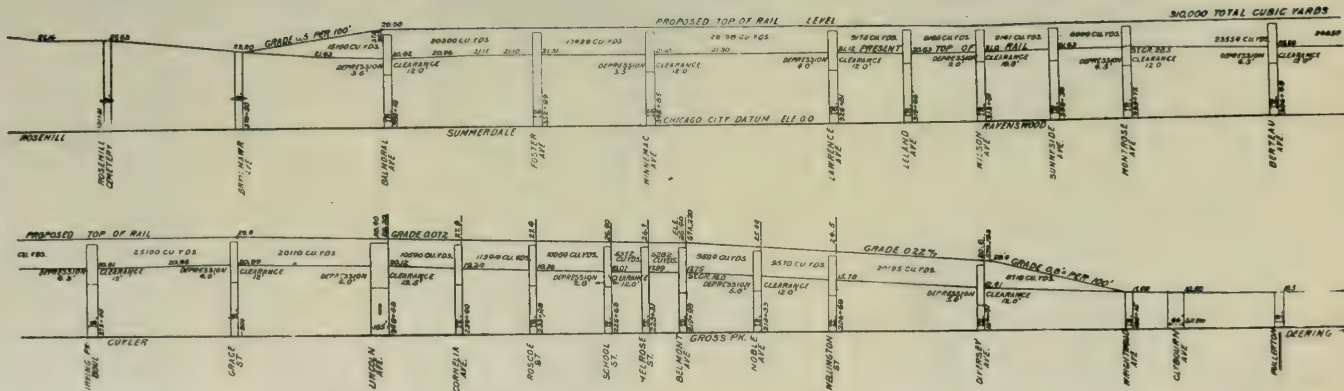


FIG. 448. PROFILE OF THE MILWAUKEE DIVISION ELEVATION, FROM DIVERSEY BOULEVARD TO ROSE HILL.

ments; 140 gondola carloads of sand were unloaded a day for a full month of this time.

This work was done in about four months and we had twenty-seven months in which to do it. The cost was only 70 per cent of the estimate, and work was so quickly done that it encouraged the company to discuss the question of elevating the other divisions, and an ordinance was agreed to for elevating the Milwaukee division between Diversey boulevard and Rosehill, Fig. 448, and the Wisconsin division between Clybourn Junction and Mayfair, $8\frac{35}{100}$ miles. (Profile shown in Fig. 449*). The ordinance was dated March 30, 1896, and had eight years to run, and it covered the outlying districts of these two divisions, and would require fewer subways than would be required if the elevation was delayed.

The work under this ordinance was started by the placing of the first bridge at Berteau avenue, on the Milwaukee division, on May 16th. The last bridge was placed at Diversey boulevard August 1st. In all 13 subways, three tracks each, in sixty-seven working days, the elevated section being $2\frac{25}{100}$ miles long. This was the portion to be elevated in 1896, and was the south end of the Milwaukee division elevation. The right of way on this division is sixty-six feet wide. The elevation was about eight feet. Two tracks were in use and a third track was laid; the two tracks were lined over about six feet as the work progressed, and the third track was laid just ahead of the elevation. Single track was maintained through the section being elevated; that is to say, about one-half mile of single track was necessary, with switches at each end, in the double track, at the north end, where it had been elevated, and into the double track at the south end just ahead of the elevation. These switches were moved as the elevation progressed; train dispatchers were at each end of the single track and prevented any delay to trains in passing over this single track section, except that the rate of speed was reduced to about ten miles an hour, making a delay to trains of not more than five minutes. The through Milwaukee trains were run via Mayfair during the progress of this work, but 76 passenger trains passed over it every day. The subways averaged about 1,000 feet apart, so the placing of bridges was not the controlling feature of this piece of work, but the unloading of sand (which amounted to 140,000 cu. yds.), as well as placing the street excavation into the fill, which amounted to 57,000 cu. yds. The cross-section of the bank was about 16 cu. yds. per lineal foot. We handled about 3,000 cu. yds. of material a day, and the work advanced at the rate of 200 lineal feet a day, necessitating the placing of a bridge every second day. This was done with regularity. On this division, as well as on the Galena Division, the streets crossed at right angles to track, with the exception of Lincoln Ave. Girders spanning the entire street, Fig. 450, were used, if the

*See folder at end of article

Fig. 450. Bridge at Roscoe Street, 66 ft. Between Abutments.

Fig. 451. Bridge at Montrose Ave., 80 ft. Between Abutments, Posts on Curb Line.

Fig. 452. Bridge at Lincoln Ave. and Addison St., Length, 245 ft.

FIG. 453. METHOD OF TEMPORARILY SUPPORTING BRIDGES ON PILING, MILWAUKEE DIVISION.

FIG. 453a. LAKE STREET SUBWAY, LOWER LEVEL; ROCKWELL STREET ELEVATION, SECOND LEVEL; LAKE STREET ELEVATED, THIRD LEVEL.

street was 66 feet or less in width; when over 66 feet posts were used to divide the span, Figs. 551-452. The bridges were temporarily placed on piles, Fig. 453, and at the full elevation, a pier of four piles being placed under each end of a bridge. This did not load the piles but little more than piles are loaded in a pile bridge, unless you consider that the outside piles of a bent do more than steady the bridge. The piles did settle some, but not seriously, and it was a very small additional expense to put a post under the end of the girder where necessary. Double track over this 2¼ miles elevated was in use August 7th; therefore, in a little over twelve weeks 2¼ miles were elevated and the traffic was on the iron bridges on stone abutments.

At Lincoln Ave., Fig.452, we had a diagonal crossing and square crossing combined, making 245 lineal feet of bridge. This bridge was as awkward as could be, but was loaded on to cars at the derrick one mile south of there, taken over 15 degrees reverse curves to the main track, straightened up after getting on the straight track and landed on the iron posts between the hours of 4 and 9 P. M. Fig. 454. The fill was made both sides of the bridge during the next two days, traffic went over the bridge the second morning. Fig. 455. More concisely, the bridge was placed on west track at 6 P. M., July 6th, traffic over it July 9th, 8:40 A. M. Bridge placed in east track, Fig.456, July 9th, 6 P.M., center floor put in July 10th in the afternoon, stone abutments started July 16th, finished July 24th, electric cars started running July 26th. Fig. 457. This bridge was the length of three ordinary street crossings, and the elevating of the tracks at this busy crossing stopped wagon traffic from July 6th to the 26th. The tracks were elevated and on iron bridges, on stone abutments, in sixteen working days. (The piers had been put in previous to the placing of the bridge.)

At Belmont Ave. a sixty-six foot square crossing, the record was as follows: Placed the bridge on west track July 20th, 4 P. M.; placed the bridge on east track July 23rd, 11:00 A. M.; traffic run on west track July 22nd at noon; less than two days required to place the bridge and make the necessary fill and put the traffic on the elevation, the bridge being carried on piles until Aug. 14th, when the masonry was finished.

The building of stone abutments, Fig. 458, in no way interferes with the elevated tracks, as the work is all done from the street level, so that two to three days was the time required to change the tracks from the original level to the elevated level. The concrete foundations were put in ahead of the elevation proper, as this section of the city has quicksand under it, and it was not considered safe to take the chance of undermining the elevated tracks.

As to the balance of this division to be elevated, eight subways remained. The bridges were manufactured in the winter of 1896 and 1897 and were ready to place as soon as frost was out of

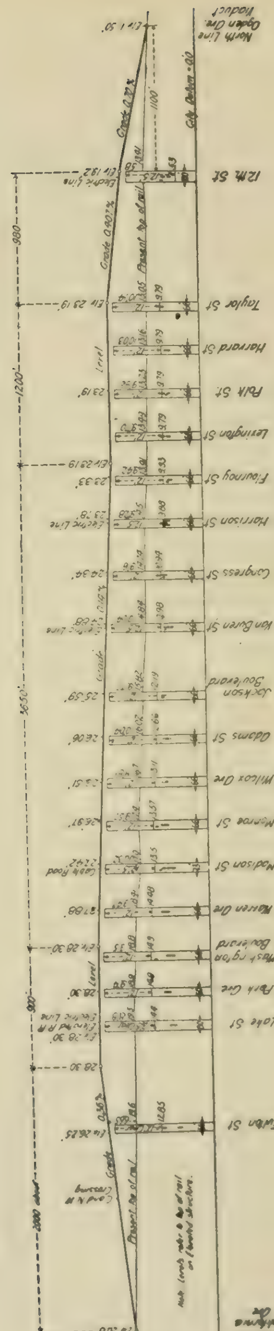


FIG. 459. PROFILE OF THE ROCKWELL STREET ELEVATION.

LINCOLN AVENUE AND ADDISON STREET.
(See also Fig. 452)

FIG. 454. WEST TRACK SPAN LOADED ON SUPPORTS JULY 6, 6:00 P. M.

FIG. 455. WEST TRACK SPAN CARRYING TRAFFIC JULY 9, 8:40 A. M.

IG 456. DRIVING PILES FOR TEMPORARY SUPPORT OF EAST TRACK SPAN JULY 9.

FIG. 457. ELECTRIC CAR CLEARANCE AND UNDER VIEW OF BRIDGE FLOOR AT LINCOLN AVENUE.

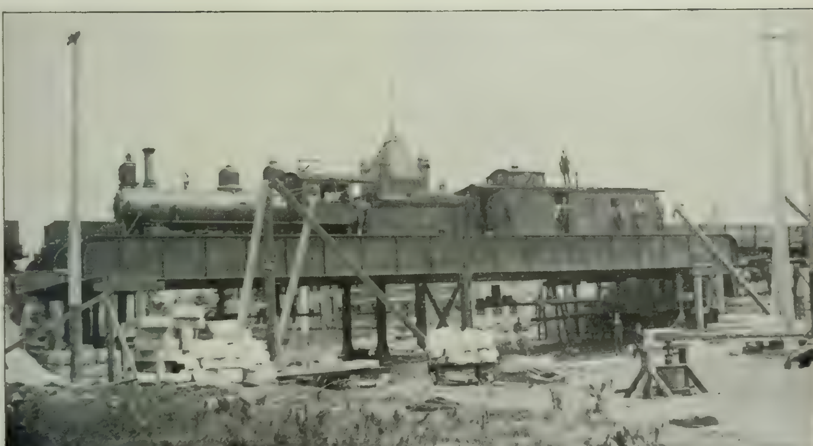


FIG. 458. IRVING PARK BOULEVARD 100 FT. CLEAR SPAN WITH CENTER POSTS. Shows also the building of stone abutments in progress.

the ground in the spring. Work was started April 14th by the placing of the first bridge at Montrose Ave., and was advanced rapidly toward Rosehill, where the last bridge was placed at Balmoral Ave. May 10th, or 21 working days for $1\frac{5}{10}$ miles of elevation. On this section of the work, and because of light travel on the streets, we placed three bridges on three successive streets, on the west track, in one day. The streets were: Montrose, Sunnyside and Wilson Aves.; distance between streets, 660 ft. We made the fill between them and put traffic over them in four days; then placed the bridges on the east track at these three streets in one day, and made the fill and put in intermediate floors so that traffic was on the east track in six days; that is, the bridges for three streets, three tracks at a street, were placed and the fill made between them and traffic put over them for a distance of ¾ of a mile, in ten days. See profile, Fig. 448.

We were 27 working days unloading sand, and averaged 146 cars, or 4,000 cu. yds. a day; 28,000 cu. yds. of street excavation was placed in the bank, which, with the 110,000 cu. yds. of sand, made the work advance about 340 lineal feet a day.

The month of May, 1897, finished this work on the Milwaukee Division, and the Rockwell St. work was ready for us, an ordinance having been passed January 18th, 1897, for elevating five or more tracks, $1\frac{7}{10}$ miles, to be finished in 1898. It was in a measure co-operative between the three Railways interested, C. &. N. W., P. C. C. & St. L. and C. & N. P. The profile, Fig. 459, and the maps, Figs. 460 and 461, show the location and conditions. By agreement I was formally engaged as Engineer of Track Elevation for the three Railway Companies, and contracts were made by each Company with the same firms for the different kinds of work to be done. The C. & N. W. R'y Co's outfit and men were to do the work and the pay roll to be pro-rated between the three Companies. No contracts or agreements were drawn between the three Railways, each road favored the work wherever necessary and it advanced rapidly. Starting June 4th, 1897, a string of bridges on two tracks (east and middle) were placed at fonr streets, Monroe, Wilcox, Adams and Jackson, Fig. 462; the fills were made and the intermediate floors put in and double track traffic put on this elevated section June 12th, 2 P. M. This first section elevated was about 1,800 feet long. The remaining bridges were placed on the west track June 13th, intermediate floors put in June 14th. Because of blocking four streets it was decided to make a temporary planked road at Wilcox, which was done June 17th. The street excavation started at once. Masonry started very soon and all branches of the work were well under way by the middle of June. The traffic was elevated over four streets, and it was decided to add a string of bridges on the west tracks over the next four streets to the north, Madison, Warren, Washington and Park Ave., so that with the next change of traffic to the west side of the elevated lines it would be over eight

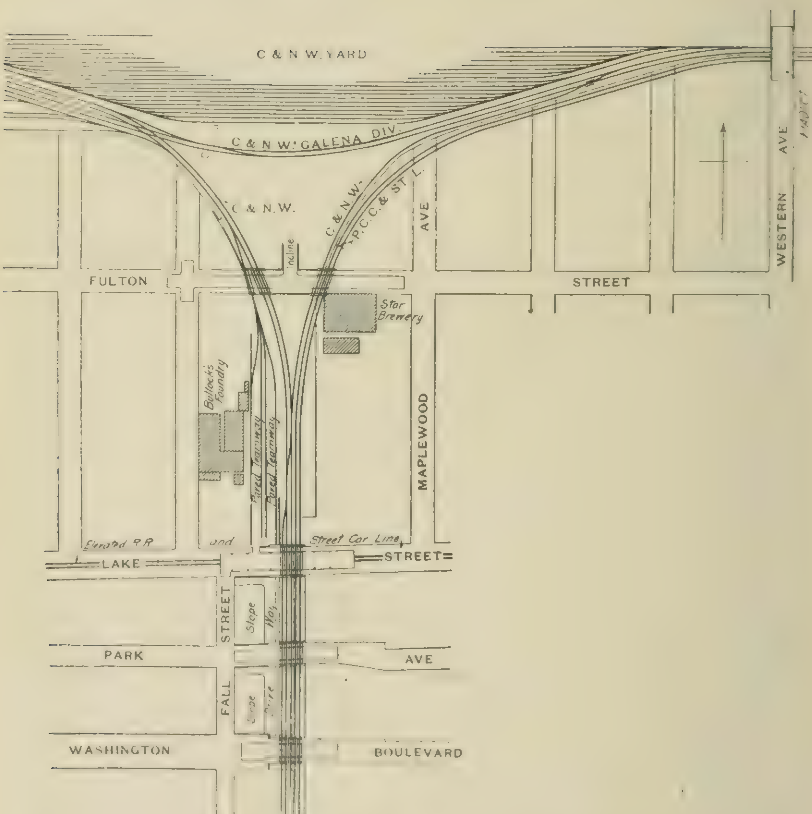


FIG. 460.

MAP OF THE NORTH END OF ROCKWELL STREET ELEVATION

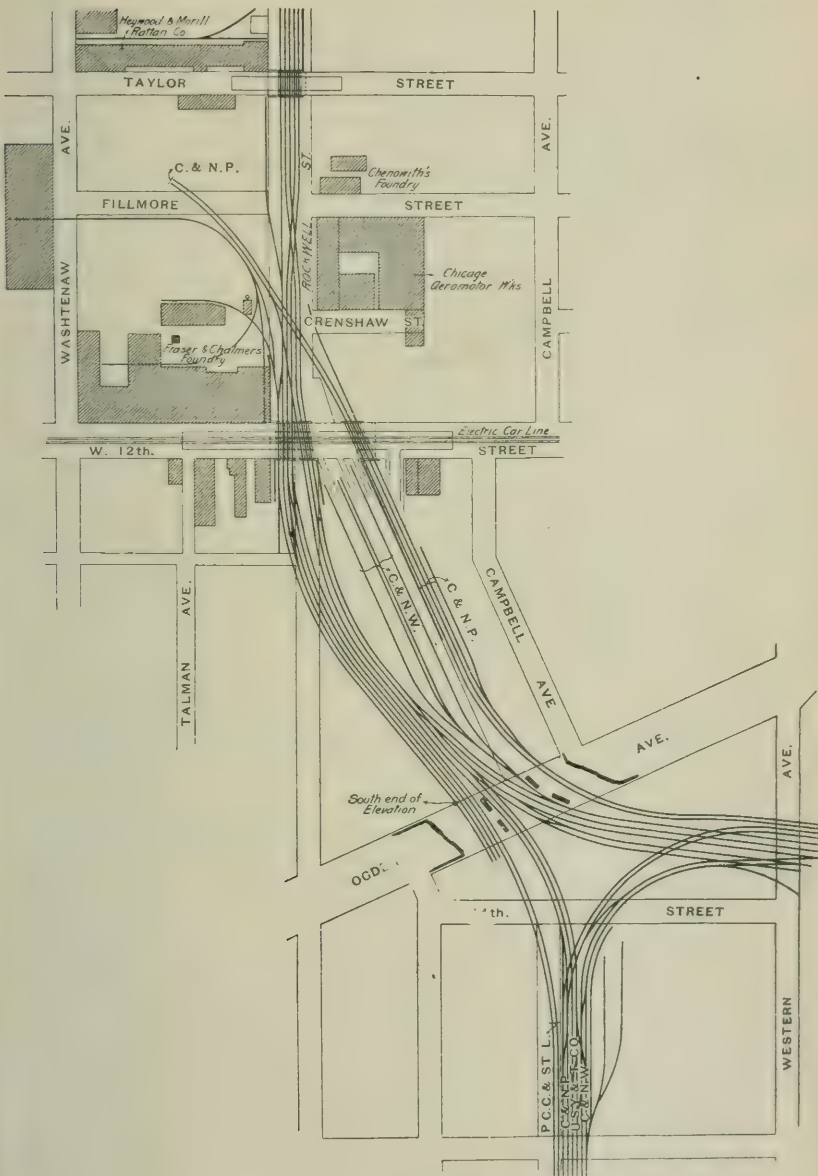


FIG. 461.

MAP OF THE SOUTH END OF ROCKWELL STREET CROSSINGS OF P. C. C. & ST. L. RY., C. & N. W. RY., AN . & N. P. RY., NORTH OF TWELFTH STREET.

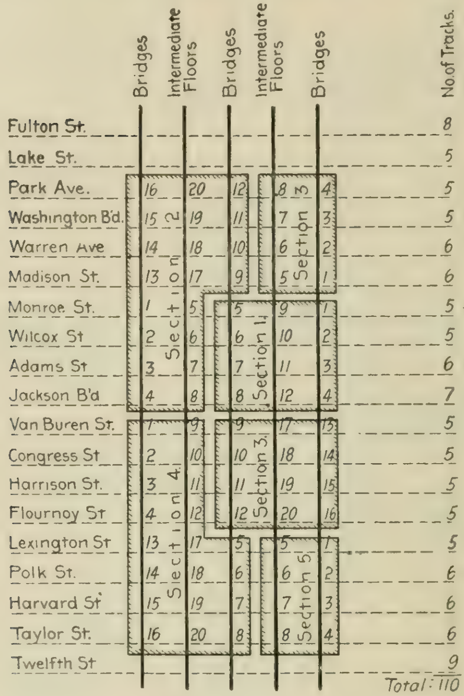


FIG. 462.

PLAN OF TRACK ELEVATION WORK ON ROCKWELL STREET LINE IN CHICAGO. C. & N. W. RY., SHOWING THE ORDER IN WHICH STRUCTURES WERE ERECTED.

bridges. In making this decision the cable line at Madison St. loomed up. The placing of the bridge at Madison St. would stop the cars. The first bridge was placed at Madison St. Friday, June 18th, at 5 A. M. An officer attempted to serve an injunction to prevent the placing of the bridge at 6 A. M., but he was too late. Saturday at 4 P. M. the injunction was dissolved, and the work started again after two days' delay. Had this injunction held, it would have stopped track elevation, except at a full elevation of 16 feet and no interference with street traffic. Traffic was placed on the west track elevated over eight streets June 25th; on the east tracks elevated over twelve streets July 12th; on the west tracks elevated over sixteen streets July 22nd.

In placing bridges at the above sixteen streets, from June 4th to July 22nd, bridges for 87 tracks were placed in 38 working days, or 2 3-10 tracks per day, and in this piece of work the rapid placing of the bridges meant rapid progress. The unloading of sand was of minor importance, but 72,000 cu. yds. of street excavation was placed in the fills, thereby making the expense of excavation for subways practically nothing. This covered sixteen

streets out of nineteen with bridges, and 12th St., the last street on the south, where there were nine tracks, was covered with bridges from July 31st to Aug. 6th.

The bridge for east C. & N. P. R'y Co's track was 125 ft. long and was landed on the temporary pile support Aug. 5th at 6 P. M.; the sand fill was made that night, so that on Aug. 6th at 6 A. M. the traffic went over the bridge single track. The girder that carried the west track was placed at 10 A. M. and the floor put in and fill made so that double track traffic was resumed at 6 P. M., thereby elevating their two tracks over 12th St. in twenty-four hours. The P. C. C. & St. L. R'y, the C. & N. W. R'y and the C. & N. P. R'y tracks cross each other about 200 feet north of 12th St. subway. This crossing was elevated eight feet and traffic maintained over the same amounting to 316 trains a day, or an average of 4,341 cars a day, all the work being done in the day time. See Crenshaw St. on map, Fig. 461.

After placing bridges at 12th St., the bridges were placed at Fulton and Lake Sts., the only streets remaining. Lake St. could not be placed at grade until the Lake St. "L" Road was remodeled. Fig. 453a. This delayed the finish until Sept 19, the men being employed from Aug. 15th to Sept. 19th in ballasting the tracks.

This section of the city has a large street traffic; bridges were only about 350 feet apart, and one street out of each four streets was made passable for teams by planking a roadway as soon as street was excavated to new grade. This proved satisfactory to the people and cost but little. By examining the table of quantities herewith submitted, it will be noticed that the nineteen subways required a large expenditure. The line being only $1\frac{7}{10}$ miles long cost as much to elevate as $4\frac{6}{10}$ miles that was elevated this year on the Wisconsin Division of the C. & N. W. R'y, between Clybourn Jct. and Mayfair. This latter line was covered by the ordinance of March 30th, 1896. It was an elevation of three tracks ten feet, and run in a northwest direction, crossing all the streets but one diagonally, increasing the street spans about 50 per cent. There are twenty-five subways and one footway on this line, as seen by the profile, Fig. 449.* Work was started by placing the first bridge on March 24th, 1898, or rather a string of three bridges on the same track, and was finished by the placing of the last bridge May 28th. Bridges for 77 tracks were placed in 58 days, or an average of 1_{10} tracks per day. The unloading of sand was the item that would give rapid progress, and our record was 343,463 cu. yds. in 58 working days, or 5,800 cu. yds. a day; 98,000 cu.yds. of street excavation were put in the fill during this time at a cost to the company of 27c per cu. yd., including overhaul. This work progressed at the rate of exactly two miles of three track railway, elevated ten feet, in a month.

The men engaged in ballasting this work during June and the first of July, were put on to track work, between Diversey Boul. and Chicago Ave., where the foundations for bridges and

*See folder at end of article.

retaining walls are being built for the section to be elevated in the spring of 1899, under an ordinance dated December 29th, 1897, shown in the profile, Fig. 464*.

This work extends the elevation of the Wisconsin & Milwaukee Divisions, previously treated of, to Chicago Ave. viaduct, and will consist of fourteen full subways, four half subways and four footways. Five miles of retaining wall are to be built this fall, all the foundations put in for the subways. 90 lb. steel is being laid for a double track for each division from Clybourn Junction to Erie St., and an outside freight track on each side of the running tracks, giving six tracks every where and in some places seven. This work will take from March to June, 1899, at which time the Chicago & North-Western R'y will have elevated its tracks everywhere that they can be elevated independent of other roads, and will have elevated the Galena Division to Western Ave. viaduct, Rockwell St. on the Belt Line to Ogden Ave. viaduct, and the Wisconsin & Milwaukee Divisions to the Chicago Ave. viaduct. That is, they will have elevated until they reach the viaduct district in every direction, and can proceed no further until the city disposes of the viaducts that they ordered built and made the roads pay for.

June 1st, 1899, the road will have elevated $14\frac{1}{2}$ miles of their terminal in Chicago; this will include 90 subways and five footways. (Seventy-two subways and one footway are now built and $11\frac{75}{100}$ miles are elevated.) This reduced to double track equals $27\frac{49}{100}$ miles, including 15,403 lineal feet of double track bridging.

There are two other small pieces of elevation that this Company has an interest in; one is for two subways near Mayfair made necessary on account of elevating the C. M. & St. P. R'y over Milwaukee Ave. and Irving Park Boul., and the other a one-fourth interest in the Air Line, where this Company's interest, since the plans were agreed to, seems to be only in a prompt payment of bills rendered. The first piece is to be elevated next year to suit the wish of the C. M. & St. P. Ry. Co., and the second is under way.

In the process of track elevation we have loaded on to cars, Fig. 466, 170 bridges and safely landed them on the temporary pile support or on the permanent iron posts, see Figs. 467-468, carrying some of them on cars as far as five miles, thereby proving the feasibility of the plan. As to the expense, the cost of the entire temporary work of placing bridges, building back walls (Fig. 469) driving piles where driven, putting track stringers where foundations precede the work of elevation, is less than one dollar per lineal foot of track, to be compared with the cost of temporary pile or trestle bridging, which costs at least five dollars per foot of track, since there would have been 44,800 lineal feet of temporary pile bridging necessary if the usual method had been followed; this saving is approximately $179,200. As to the chance

* See folder at end of article.

FIG. 465. STONE DERRICK IN STORAGE YARD.

FIG. 466. COMPLETE SPAN LOADED ON CARS FOR DELIVERY ON WORK.

FIG. 467. LONG SPANS IN POSITION ON PERMANENT IRON POSTS.

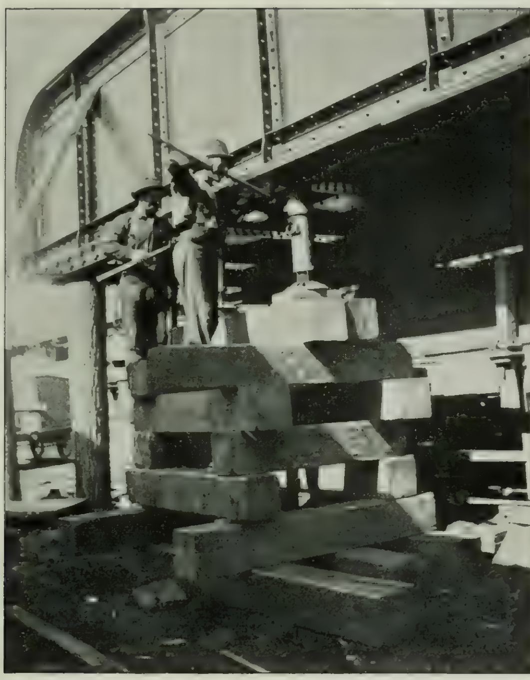


FIG. 468. LOWERING BRIDGE SPAN ONTO PILE SUPPORTS.

FIG. 469. TEMPORARY END SUPPORT AND BACK WALL.

of rushing the work (as the President of this Railway was anxious to do—considering the process of elevation a nuisance, and the shorter the nuisance the better), there is no questioning the fact that three tracks elevated ten feet for a distance of two miles in one month, is a more rapid progress than any other road has made to date, and this, too, at no additional cost.

Traffic over the Galena Division, the first piece elevated, was 294 trains a day, 2,619 cars. Traffic was interfered with from April 15th, 1895, to July 10th, 1895. Double track interfered with during elevation, 1.89 miles of five tracks interfered with 55 days.

On the Milwaukee Division the traffic consisted of 76 trains a day.

It was interfered with from June 16, 1896 to Aug. 7, 1896, 51 days.

It was interfered with from Apr. 12, 1897 to May 12, 1897, 30 days.

Single track interfered with during elevation, $3\frac{6}{10}$ miles, 3 tracks, interfered with 81 days.

On the Rockwell St. Line, $1\frac{7}{10}$ miles, the traffic is 195 trains, or 3,171 cars a day, except on the 12th Street crossing, where it equals 316 trains, or 4,341 cars a day.

While work was in progress the tracks of the C. & N. W. R'y were used in common by the P. C. C. & St. L. R'y and their tenants, the C. M. & St. P. Ry. Co., for 52 days; the P. C. C. & St. L. Ry. Co.'s tracks were used in common by the C. & N. W. Ry. Co. for 23 days—traffic being thus interchanged 75 days—but a double track was maintained all of the time. This arrangement started June 1st, 1896, and each road had a double track elevated Aug. 24th, $1\frac{7}{10}$ miles of 5 tracks in 80 days.

On the Wisconsin Division, $4\frac{6}{10}$ miles, the traffic is 55 trains a day.

Single track during elevation in mile sections was interfered with from March 24th to June 4th or $4\frac{6}{10}$ miles of 3 tracks, for 73 days.

The summary is, therefore, track elevated in four different parts of the terminal, covering a length of right of way of $11\frac{78}{100}$ miles, three and five track systems, which reduces to $21\frac{2}{100}$ miles of double track, having 10,655 lineal feet of double track bridging spanning 72 subways, with interference with traffic amounting to 289 days, or about ten months. The graveling of the elevation proceeded rapidly in each instance, so that with the above intervals excepted, a speed of 25 miles an hour could be maintained over the different portions elevated.

Regarding the bridge design. The floor, Figs. 470 and 471, is 12 inches thick and consists of floor beams built of two 10 inch channels with top and bottom plates connected to the girder, with a ½ inch gusset projecting two feet, that goes between the channels—a filling piece extends from gusset to gusset. These beams are about 5 feet apart and track stringers made of two "Z" bars about 10 inches apart, carrying an oak block 16 inches wide and 6 inches to 7 inches thick, connects them. The varying thickness of block

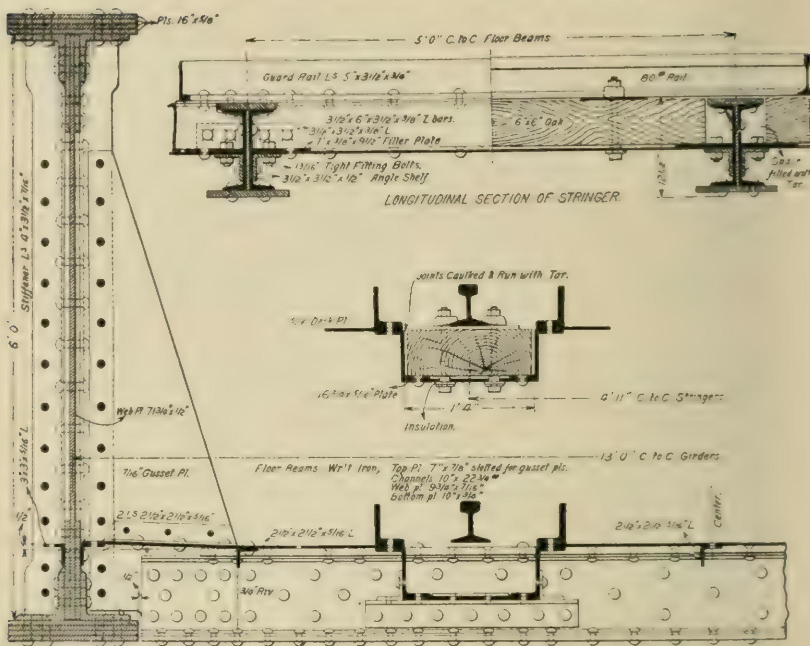


FIG. 470. SECTIONS OF BRIDGE FLOOR, C. & N. W. RY.

levels the rail and allows of one inch camber in girders for drainage. A 5 inch angle iron is riveted to the top of the "Z" bars on each side of track stringers to strengthen them, as well as to guide derailed wheels. The bridge floor is covered with $\frac{5}{16}$-inch plates which are stiffened by small angles breaking the large surfaces. This covering plate is covered with a coat of gravel roofing to protect the iron. The floor beam is designed for one axle 40,000 lbs., one panel floor 4,000 lbs., length 12 feet. This requires that the gusset shorten the span of floor beams one foot, and since each gusset projects two feet, I think the reasoning is correct—at any rate, the floor is very rigid.

The double track girders are designed for 4,000 lbs. per lineal foot plus 1,400 lbs. dead load, making 5,400 lbs. per lineal foot. The metal is strained 9,000 lbs. per sq. in. net section in tension. The outside single track girders are designed. 2,500 lbs. plus 850 lbs., making 3,350 lbs. per lin. ft. Weight of floor is 531 lbs. per lin. ft. of bridge; this does not include the gussets or guard rails.

A girder for double track 66 ft. square street crossing weighs 41,000 lbs. Amount of metal in C. & N. W. elevation, including work under process of elevation, 21,747 tons.

The abutments for bridges were of concrete foundations and Duck Creek dimension stone cut at the Company's quarry for face stone, with Lemont rubble for backing; the dimension stone

FIG. 471. SHOWING CLEARANCE AT BRIDGES WITH TRACKS 13 FEET CENTER TO CENTER. Top of highest Girder, 5 feet above top of rail, or 1½ feet below car window. Girder 16 inches wide. Clearance 10 inches.

FIG. 472. EIGHT-INCH I BEAM, TROLLEY AND TWO-TON HOISTING BLOCK USED IN LAYING DIMENSION STONE IN ABUTMENTS.

was distributed for setting by a trolley, Fig. 472, carried by an 8-inch I beam suspended from the lower flange of girders; this trolley carried a 2-ton Yale & Towne block. Stone was unloaded from cars on one piece of work by a derrick fixed to the outside of girder, having a boom swinging over the car; this required one track to work from; a horse-power on the street handled the stone being unloaded. 120 cubic yards per day have been laid in this way, in a good many consecutive days. The record on the Wisconsin Division—26 subways built this year—is as follows: Started work April 5th, finished 52 abutments July 7th, 9,397 cubic yards in abutments, or 117½ cubic yards per day, or one subway in $3\frac{1}{10}$ days.

On another piece of work we used a steam derrick instead of the fixed derrick. This requires a track for the derrick and another for the stone train, and was not as satisfactory.

The plan of abutment was a large pedestal block 5 ft., x5 ft., x1½ ft., carrying a casting about 18 inches high; this gave room to use the jacks under bridges on the stone work to line the bridge before being bolted to masonry.

The foundation concrete was made of American Portland cement for the piers, and of native cement for the abutments. The Railway Company furnished all the material used, so there has been no incentive to stint the work.

The responsibility of handling the work was arranged for as follows:—

Wm. Graham designed the bridges, arranged for their delivery on the work and assembling.

G. C. Chittenden had charge of all track work and train crews.

T. R. Philbin had charge of all work on subways.

T. Gilmore placed the bridges and maintained them until on permanent support.

C. H. Kilpatrick had charge of material and labor accounts.

All subway work was done under contract.

The sand filling was purchased f. o. b. cars C. & N.W. tracks.

Bridges were purchased erected.

The force of subway contractor averaged about 200 men.

Bridge erecters averaged about 50 men.

C. & N. W. R'y Co's force averaged about 350 men.

The following detail of the work may be looked into by any one specially interested:

	Galena Div.	Milwaukee Div.	Rockwell St. Line	Wisconsin Div. Clybourn Jct. to Mayfair.	Wis. & Milw. Divs. Wrightwood Ave to Chicago Ave.	Totals.
Miles	1.80	3.75	1.70	4.60	3.00	14.85
Tracks	5	3	5 & 6	3	6	
Cubic Yards						
Sand Filling	275,000	250,000	177,000	343,000	450,900	1,495,900
Street Excavation	30,000	85,000	72,000	98,000	76,000	361,000
Gravel Ballast	52,000	50,000	20,000	50,000	50,000	220,000
Masonry Abutments and Foundations	7,300	11,500	17,000	21,000	21,150	77,900
Rubble Retaining Walls & Foundns.	2,100	2,160	9,200	......	50,000	63,460
Tons of Bridge Metal	1,645	3,114	5,540	5,598	5,650	21,457
Square Yards						
Paving	11,500	31,000	36,400	38,500	33,400	150,800
Sidewalks	7,000	13,000	14,700	17,000	24,300	76,000

SUMMARY OF ALL TRACK ELEVATION IN CHICAGO TO DATE.

Lake Shore & Mich. Southern R'y / Chicago. Rock Island & Pacific R'y	6.5	Miles Elevated.	39 Subways.
Illinois Central R. R.	2.5	" "	12 "
Pittsburg, Ft. Wayne & Chicago R'y	2.0	" "	13 "
Chicago, Milwaukee & St. Paul R'y	2.0	" "	12 "
Total by other Railways	13.0	" "	76 "
Chicago & Northwestern R'y	11.8	" "	72 "

NOTE.—Figs. 446, 448, 459, 460, 461 and 470 are reproduced from *The Railroad Gazette*, and Fig. 462 from *The Engineering News*.

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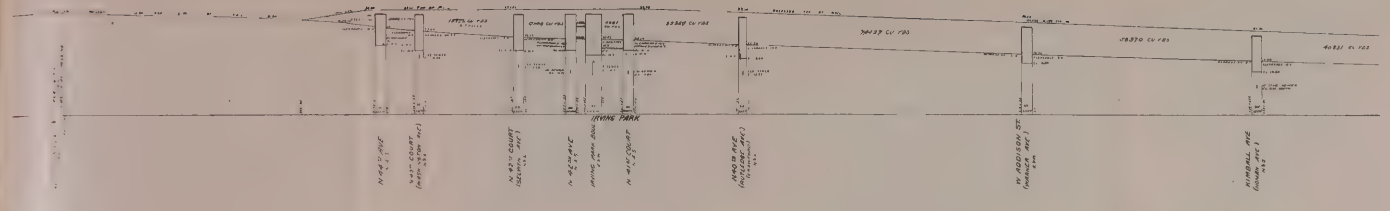

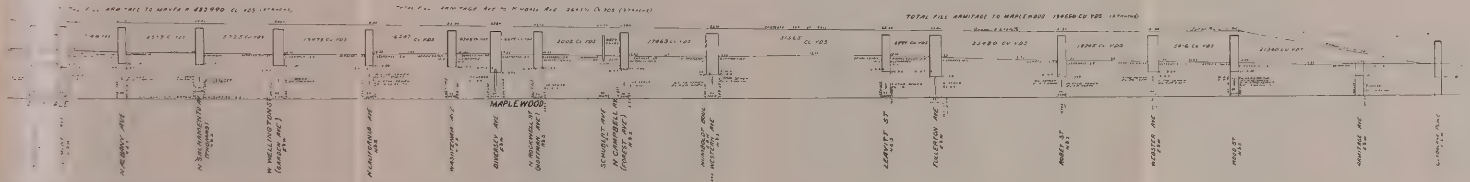

Fig. 4[illegible]. Profile of Wisconsin Division Elevation between Clybourn Junction and Mayfair, 4[illegible] miles

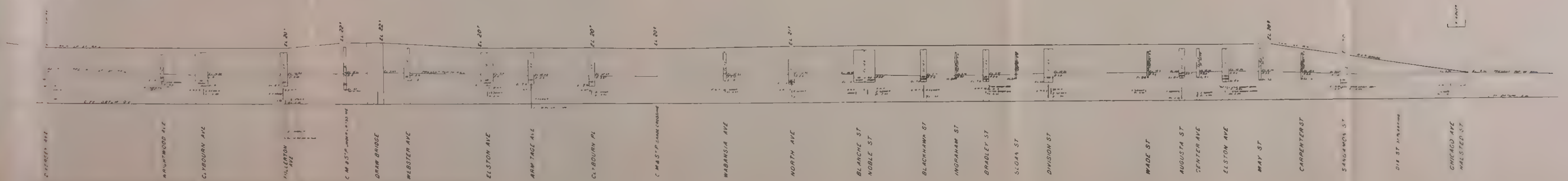

Fig. 464. Profile of Elevation between Chicago Avenue and Diversey Boulevard.

XLVIII.

ELEVATION OF TRACKS OF THE PITTSBURG, CINCINNATI, CHICAGO & ST. LOUIS RAILWAY.

By THOS. H. JOHNSON, C. E.*

Read October 5, 1898.

Replying to your request for notes on the elevation of tracks of this Company to be used in connection with the discussion of Mr. Evans' paper, I beg leave to say that the track elevation on the lines of this Company between 12th Street and Fulton Street was so closely associated with similar work on the parallel tracks of the C. & N. W. R. R. as to require all the work to be done as one connected job; and for this reason the elevation of the tracks of the P. C. C. & St. L. Ry. was placed in Mr. Evans' charge, who handled both ours and the C. & N. W. at the same time.

No doubt that whatever interest attaches to the execution of that work will be fully treated of by Mr. Evans in his paper, so that I could add nothing of interest or value to what he may say, except one point which his modesty may lead him to omit.

I desire to express my appreciation of the thoroughness with which Mr. Evans had studied the problem in advance and evolved a scheme of handling the work in the shortest possible time with the least interference with traffic, which proved to be most efficacious. In this instance the work embraced the elevation of five tracks for nearly two miles of distance, with nineteen subways. The work was begun about the first of June, and practically finished in ninety days at a cost well inside of the estimate. This I regard as a very favorable showing, the credit for which belongs to Mr. Evans.

I have no doubt this paper with the notes and discussion which it brings out will be extremely interesting and valuable as a monograph on the subject of track elevation.

*Chief Engineer P. C. C. & St. L. Ry.

XLIX.

TRACK ELEVATION IN HYDE PARK, CHICAGO, OF THE ILLINOIS CENTRAL RAILROAD.

By H. W. Parkhurst, Mem. W. S. E.*

Read October 5, 1898

In order to supplement other papers on Track Elevation in and near the City of Chicago, the writer has been requested to give a brief account of the first piece of work of this character which was done in the city, namely, the elevation of the Illinois Central tracks at Hyde Park. As this is somewhat ancient history, the writer will make as brief a description as possible, and take up such matters as may be thought of interest in subsequent discussions which may arise

Sometime in the year 1891, the subject of elevation of tracks opposite the proposed site of the World's Fair was fully discussed by the officials of the Illinois Central road, and under the direction of Mr. J. F. Wallace, then Engineer of Construction for the company, the writer made numerous sketches and estimates for the proposed work. The ordinance of the City of Chicago for the elevation of tracks was passed on the 23rd of May, 1892; was approved by Mayor Washburn May 31, 1892, and was accepted by the Illinois Central Railroad Company on the 18th of June following. In brief, this ordinance provided for the elevation of all the tracks of the Illinois Central Railroad from the north line of Fifty-first street to the south line of Sixty-seventh street, a distance of a little over two miles; providing further that such gradients as desired by the company should be adopted for the approaches at each end of this elevation, and limiting these gradients to a termination at Forty-seventh street on the north and at Seventy-first st. on the south. This makes a total of a little over three miles within which the work of elevation was carried on. For the north half of this distance, the Illinois Central had eight tracks in operation at the time the ordinance was passed, and at the southern end, seven tracks were in operation. Beside these, there were several sidings and also connections from the main line tracks to Washington Park in the vicinity of Sixty-first street and to Oakland Cemetery near Sixty-seventh street.

The ordinance provided for the construction of a roadbed of sufficient width to carry ten tracks. It provided that all the streets then crossing the railroad from 51st to 67th streets inclusive, should be carried underneath the proposed elevated tracks by means of subways, and added to these several other streets which should be opened and provided with subways. The only streets which do not extend across the railroad line are 52nd, 61st

*Engineer of Bridges, I. C. R. R.

FIG. 473. PORTAL OF FOOTWAY TUNNEL AT 62D STREET.

FIG. 474. 51ST CROSSING.

FIG. 475. SUBURBAN TICKET OFFICE AND PASSAGEWAYS UNDER TRACKS AT 60TH STREET.

and 62nd. At 52nd street, houses obstructed the extension of the street on both sides of the right way. At 61st street and 62nd street, the grounds adjacent to the tracks were so subdivided that streets could not be extended across the tracks, and at 62nd street a tunnel eight feet wide Fig. 473 was provided for a foot-way. This runs from the street on the East side to an alley on the West.

The headroom provided at the different streets varied from eleven feet at 51st Fig. 474 and 53rd streets to twelve and one-half feet for all streets south of 63rd street inclusive. During the construction of the work, the headroom at 63rd (Fig. 476) street was increased to thirteen and one-half feet, to accommodate the Chicago City Railway. The general level of the original streets was from ten to eleven feet above Chicago datum, except from 65th to 67th streets inclusive, where the ground was lower. The required headroom was obtained by depressing the streets the necessary amount and by making approaches on either side having grades of approximately four per cent.

The ordinance provided that the floors should be crossed by girders having solid, that is, water tight floors, the girders carrying which might be supported at the curb lines by rows of posts, thus dividing the structures into three separate spans. It was further provided that the girders extending over the sidewalks might be made as much longer as the Railroad Company desired, and that the space underneath these might be used by the Railroad Company as might be found advisable. During the World's Fair a portion of these spaces was occupied by booths, and since that time, nearly all of them at the sites of local suburban stations (Fig. 475) have been occupied by ticket offices, waiting rooms, etc. They also furnish passageways which may be utilized in getting from one class of trains to another. Stairways have been provided at the abutments of those subways situated at local suburban stations, so that crossing of tracks at grades is entirely avoided.

The general style of construction (Figs. 474-477) adopted for these subways consisted of the construction of masonry abutments extending nearly or quite across the whole width of the right of way (two hundred feet); the construction of isolated piers just within the curb lines for the support of a series of posts supporting the girders which cross the streets, and the ends of the girders crossing the sidewalks. Tracks are spaced thirteen feet apart centers, except in one case where the distance is fifteen feet. Tracks are so located on the right of way that ultimately a retaining wall can be built along the East line of the right of way and the nearest track will be seven feet from the right of way line.

A general type of solid floor is indicated in the illustrations. It is known as the "Lindsay" floor. This was patented in England, but I think was not patented in the United States. Rolls for making sections of this flooring were known tobe owned by the

Pencoyd and the Carnegie Companies, and invitations for the superstructure requested proposals based on floor made of these sections. Bidders were also requested to make proposals on other styles of flooring. The Lindsay floor was finally adopted in the belief that the material could be obtained most readily, and that for an equal weight, the distribution of the metal was the most economical of any of the styles of floor suggested by the several bidders.

Figs. 478-479-480-481 show the details of the floor that was actually used. Floor was first constructed as shown in Fig. 478 Ties were made small enough so that they could be placed in the troughs, and the rail was laid upon them, the tie being high enough so that the rail would clear the top of the trough.

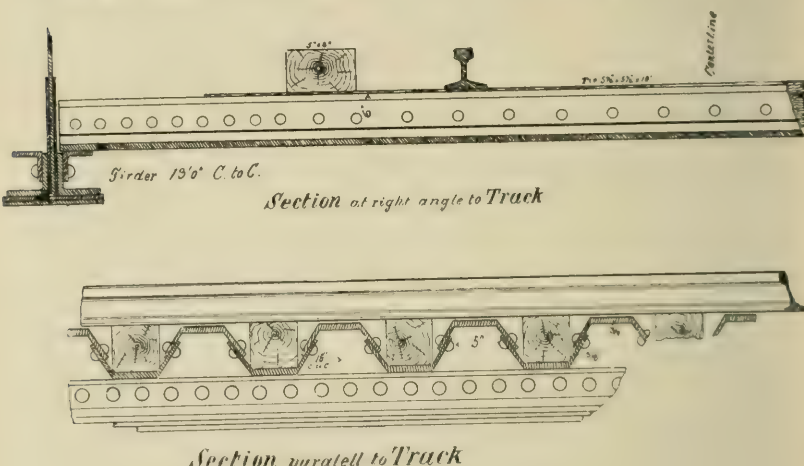

FIG. 478.

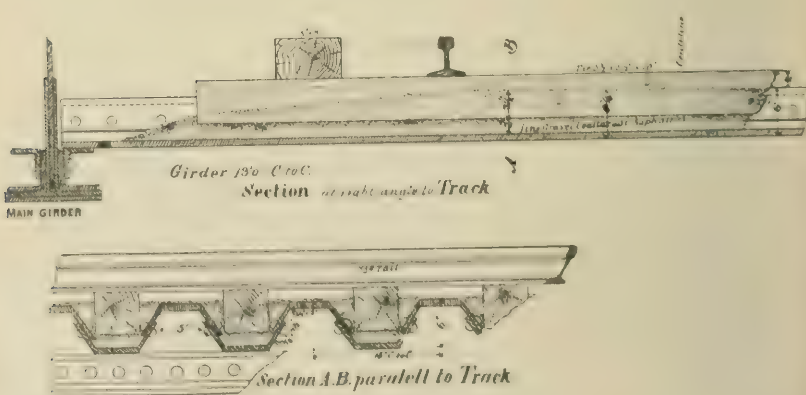

FIG. 479.

FIG. 476. 63D STREET CROSSING OF STREET RY., ILLINOIS CENTRAL R. R. AND SOUTH SIDE ELEVATED R. R.

FIG. 477. 67TH STREET CROSSING.

FIG. 483. 60TH STREET CROSSING DURING CONSTRUCTION.

Fig. 479 shows the plan that was intended to be carried out for this work, the ties being raised about one and one-half inches to two inches above the level shown in Fig. 478, and the space between and around them filled with asphaltic concrete. As a

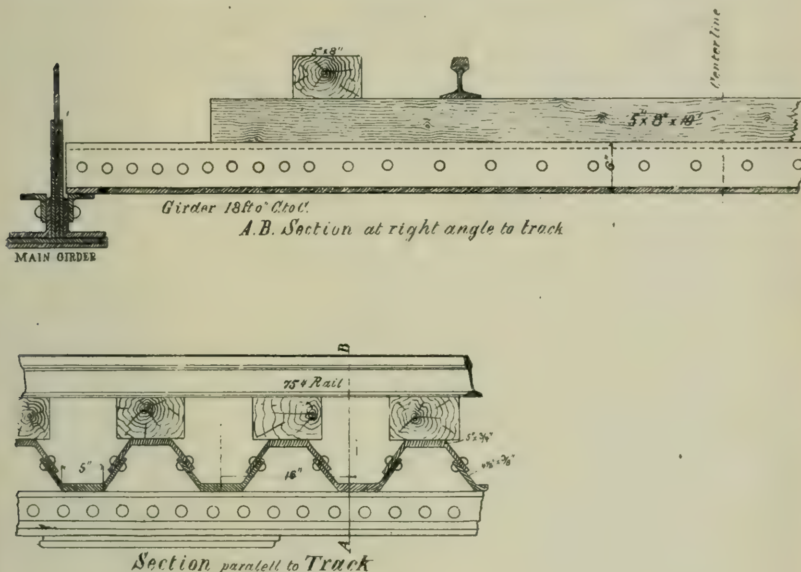

FIG. 480.

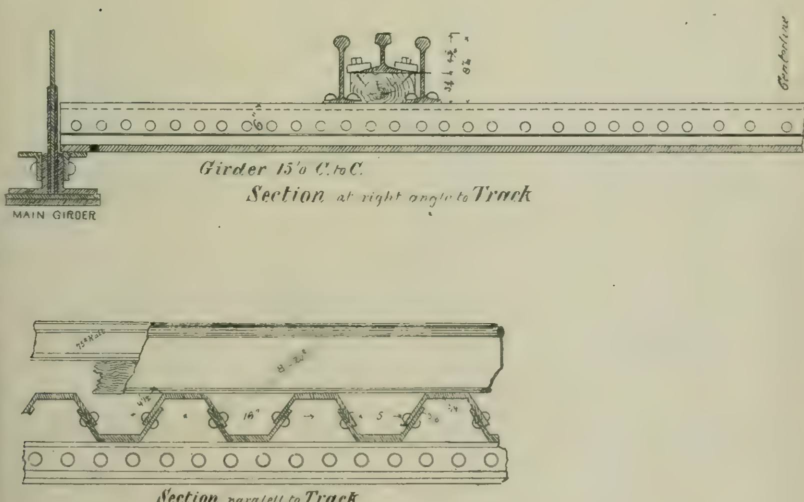

FIG. 481.

matter of fact, however, the business over these tracks was so very heavy during the World's Fair year, that it was impossible to get possession of any one continuous track to do this work, and the tracks were so operated that it was not possible to transfer business from one track to another; so that the plan shown in Fig. 480 was finally adopted to give access to the troughs for cleaning and painting; the ties being placed on the tops of the upper trough section, and being held in place by guard rails, and, where necessary, by short struts between the sloping side of the trough and the tie, one or two being used at each end of each bridge.

Fig. 481 shows the device that was used for the flooring where the girders were fifteen feet, center to center. Two deck beams are riveted to the top of the troughs in parallel lines, spaced sufficiently far apart to receive an oak timber, upon which the rail is supported and secured by means of clips. As this rail carries a track circuit, devices were used for insulating the rail.

Fig. 482 shows a form of this style of floor which has been used in one or two other places (not, however, on elevated work). The trough flooring in this case is filled with ballast and the ties are spaced at random above the same, and the space between them is filled with ballast in the usual way, although this is not shown in the drawing.

With reference to the "Lindsay" floor, the writer would call the attention of the members of the Society to the paper written by Mr. Henry Goldmark, and read before the Society some three years ago, in which he analyzed the strains upon this floor and showed conclusively that, although somewhat flexible, the track rail distributes the concentrated loading over so many sections of

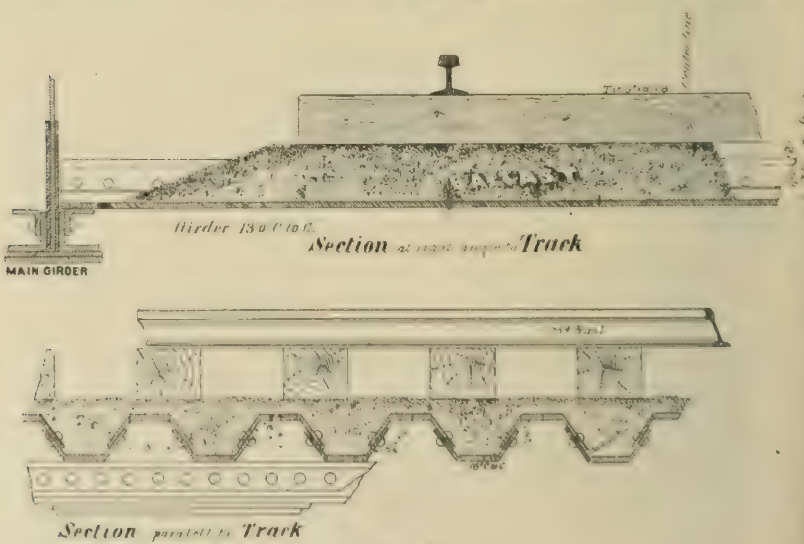

FIG. 482.

FIG. 484. GENERAL VIEW OF HYDE PARK ELEVATION OF ILLINOIS CENTRAL R. R. (8 TRACKS), LOOKING NORTH. 57th Street Station in the Foreground.

the floor that there is no question of its strength. In corroboration of Mr. Goldmark's mathematical deductions, the writer has made graphical tests of the actual deflections of these sections of flooring under loads of all classes of engines, cars, etc., which are carried over the Hyde Park elevated work. In no case is the deflection excessive. The calculated strains due to these deflections are entirely within safe limits, and it should be borne in mind that the measured deflection takes into consideration all strains due to vibration, impact, etc.

Detail drawings for the work were prepared in the Illinois Central Company's offices, and the work was actually begun in the field and in the bridge shops early in June, 1892. The first earthwork in connection with the elevation of tracks was begun the latter part of May, 1892.

The method of work adopted was as follows: Commencing at the extreme east side of the Company's property, an embankment of sand was built and a track was laid on the same. This track was raised as high as possible, first making steep gradients down to the crossings of the several streets which were necessarily kept open for traffic, and finally pile and timber trestle work (Fig. 483) was constructed at these street crossings and the track was connected on the same; the filling was widened to the West and, as fast as was required, additional lines of trestle work were built across the streets. At the Midway Plaisance (Fig. 483), which had to be left open for World's Fair purposes, a pile trestle work was driven and this was maintained until the year following the close of the World's Fair. The first elevated track was put in operation early in November, although two tracks were used for a day or two at the time of the nominal opening of the World's Fair late in October, 1892. The last tracks to be used on the original surface of the ground were the two west ones which were the local suburban tracks. Track No. 1, the extreme west one, was abandoned on the 20th of January, 1893.

The erection of the superstructure was begun on the easterly side of the several street crossings and was pushed forward, generally extending from east to west across the several streets (Fig. 484). The whole work was completed late in the spring of 1893. It should be understood, however, that at the Midway Plaisance the pile trestlework above referred to was not replaced until late in 1894, this work being completed in the spring of 1895.

There were twelve subways across as many different streets, varying in cost from $30,000 to $70,000, not including the subways at 59th and 60th streets, adjacent to the Midway Plaisance. These in their present condition cost about $90,000 each.

The work done in this piece of track elevation consisted in making an embankment containing about eight hundred thousand cubic yards; building about sixteen thousand yards of masonry of all classes, and putting in place about six thousand three hundred tons of iron and steel in the bridges. The cost of the whole work was about $1,400,000.

L.

TRACK ELEVATION OF THE CHICAGO, MILWAUKEE & ST. PAUL RAILWAY.

Papers by Messrs. Webb, Rogers and Reichmann.

By W. L. Webb, C. E.*

Read October 5, 1898.

Track elevation on the Chicago, Milwaukee and St. Paul Railway was begun in March, 1898, and during the season two miles of four track road, three-quarters of a mile of double track road, and half a mile single track road have been elevated, making a total of ten miles of track raised an average height of ten feet.

Ten subways were to be constructed under the four-track road and one under the double-track road.

The ordinance requiring this elevation was not passed until February 21 of this year, and on March 9 the Chief Engineer received instructions to proceed with the work. In anticipation of the ordinance, surveys had been made during the winter to procure general information in regard to the work, but plans for the work had not been made.

It was decided to do all the work of actual construction by hired labor and not by contract. This was a decided innovation, except for the bridge work, as it had been the custom of this company to do this kind of work by contract. We had no previous organization for such work to draw on, but had to start fresh.

Work on the plans was at once started, contracts for material were let, the construction force was organized, and work was begun by excavating for the foundations of the Spaulding avenue subway on March 14, and track work was started March 28.

We were instructed that no diversion of traffic was practicable. This meant that the tracks to be elevated were to be burdened with nearly the whole traffic coming into and going out of Chicago on the Chicago, Milwaukee & St. Paul Railway, and with the transfers to and from the Belt Railway and transfers between our Western Avenue Yard and our North Chicago Yard. We were also requested to so arrange our work as not to interfere with the regular trains. As we could not expect to get the permanent bridges for several months, after beginning work, it was necessary to build substantial temporary bridges across streets where subways were to be constructed to carry this traffic with safety.

The plan of temporary bridge selected was a timber trestle on a pile foundation. These bridges were located at intervals of about 800 ft., and the driving of the piles for their foundations was a source of conflict between the pile driving crew and the

*Engineer of Track Elevation C. M. & St. P. Ry.

men unloading sand, because each wanted to be on the same track at the same time and generally at the same point on the track, and it was a day of rejoicing to all concerned when the driver finished its work.

The sand for forming the embankment was received in gondola cars and unloaded by hand. The track to be elevated was "jacked up" three or four feet, and supported on piles of sand or on stakes, and the sand was then thrown on it from a train on an adjoining track. The timber trestles at the subways were built to the temporary height of the track, and the track connected across them, and the sand trains were run on it. The adjoining track was then raised as high as possible without interfering with the other tracks, and this process continued until all the tracks had been raised to the desired height.

We are fortunate here in Chicago in being able to get sand for this purpose. It is a pre-eminently suitable material. It is easily handled, runs through the track without sticking, is always clean, and furnishes a solid support for the track. Rain only makes it more solid, and our experience is that banks made of it do not settle anything like so much as those made of clay or loam; but it drifts badly with the wind, and in very windy weather it required constant attention to keep the track clear.

It was greatly to our advantage that a large portion of the section elevated was four-track road. We were enabled to devote two tracks at a time to traffic and have two tracks left for construction purposes over about one-half of the section. Where this was not possible, we were forced to unload the sand train while standing on the main tracks, as we were compelled to devote two tracks to traffic at all times. The delay caused by having to keep out of the way of regular trains resulted in a large increase in the cost of the work in the vicinity of Pacific Junction, where the complete re-arrangement of the tracks, together with the complications resulting from the flow of traffic in so many directions, made frequent changes of conditions with resulting changes in the plan of doing the work. During the months of April and May conditions were favorable, and the cost of unloading sand averaged four and one-half cents per cubic yard. During the months of July and August, with unfavorable conditions, the cost was seven and three fourths cents per cubic yard.

It is necessary to so arrange the work as to have plenty of room for unloading sand, so that men raising track and those unloading sand will not interfere with each other This required the work to be spread over a considerable length of track. Our sand trains consisted of twenty-five to thirty cars each, and when working to the best advantage we unloade six trains per day, and the work spread over a distance of about one mile.

As soon as the temporary bridges were elevated sufficiently, excavations in the subways were begun so as to get all the material excavated into the bank. This is a larger item than might be imagined and should be looked after carefully.

When these excavations were completed, the concrete piers and abutments were put in. Changes in sewers and water pipe were not made until after the temporary bridges were removed and the permanent bridges were in place. About August 1st the permanent steel bridges began to arrive, and at present seven four-track girder bridges have been completed, and two others nearly completed.

On account of the drifting of the sand, it was decided to cover the slopes of the bank with loam to the depth of one foot. This loam was received in gondola cars, and unloaded by hand in the same manner as the sand. For this purpose about 15,000 cubic yards of loam were required.

The tracks were ballasted with gravel to a depth of nine inches under the tie.

During this season 260,000 cubic yards of sand have been put into the work.

During the six months the work has been in progress, there have passed over it (exclusive of construction trains) 440,000 freight cars in 10,700 freight trains, besides 10,000 passenger trains. The average per day is 60 freight trains and 58 passenger trains, making a total of 118 trains per day. Of these, less than half of the freights and more than half the passenger trains passed during working hours, so that the average during working hours was about 60 trains, or one train every ten minutes.

From this it is easily seen that work done from the main tracks was necessarily very expensive on account of the lost time. This fact has so impressed us that for next year's work between Pacific Junction and Grayland, where there is a double track to be elevated, we are building two temporary tracks along the edge of the right-of-way upon which the traffic trains will be run during the time the main tracks are being elevated.

In preparation for this work, we will also drive piles for the temporary bridges and put in the foundations for the abutments this year. With the preparations we are enabled to make in advance, and with the experience gained from this year's work, we expect to make a much better showing next year both in the amount of work done and in the cost.

LI.

By W. A. Rogers, C. E.*

Read October 5, 1898.

Mr. Webb has just told of the work of elevating the road-bed of the Chicago, Milwaukee & St. Paul Railway:

Mr. Reichmann, who follows, will tell of the plans of the abutments and girder spans of the subways; and the writer will give a description of the part taken in the field by the Bridge & Building Department of the road.

FALSEWORK.

During the process of elevation, the tracks of this railway (four in number, except at Lawndale Avenue where there are two tracks; and at Spaulding Avenue where there are five tracks) were carried across the streets at which subways were to be built on timber bridges. The method adopted was as follows:

Bents of three piles each, located to span the abutments, pedestals, water, sewer and other pipes, were driven at each street before the tracks were raised at that point. These piles were cut off in a plane parallel to the final grade, and as near as practicable to the base of rail as it then was.

As soon as the tracks on each side were raised to a sufficient height, caps, stringers and ties were placed on the piles. Ordinarily the first raise made was about four feet, permitting the use of two caps as well as the stringers and ties. The subsequent raises were made by the use of 12 x 12 inch posts, ranging from three feet to eight feet in length. As a rule the full height has been reached in two lifts for any one track. These lifts were made by jacking under the top of the two caps until high enough to put in three, four, or five foot-posts, making a raise of from seven feet to nine feet from the original grade. Lastly, the floor was again raised as before until it was at the final height, when the short posts were replaced by posts of the length necessary to bring the track to grade.

The three stages of this operation are shown in the accompanying illustrations:

Fig. 485. Shows the Le Moyne Street Crossing, with the track in the foreground carried across the street on a floor, with double caps resting directly on the piles. Back of this track are shown two tracks raised a lift higher, and carried at this height by means of either three or four footposts. The fourth track is at a lower level and cannot be seen.

Fig. 486. Is a view of the Hirsh Street Crossing, with the track in the foreground just raised to grade from the height of the

*Engineer of Subways, C. M. & St. P. Ry.

track in the background. Part of the posts are already in place. The operation of raising by means of a screw-jack placed at each end of each cap is plainly shown. The previous height of the track is shown by the position of the rails on the bank at the right.

Most of the piles used were second-hand, gathered from the stock on hand at various points on this railway. They were from twelve feet to eighteen feet long. Some were the tops cut from piles driven for pile foundations by track-drivers; others were good tops of piles taken from pile-bridges, which had been recently renewed; and others had been used in falsework, and had been either pulled or cut off at the surface of the ground or water. The only requirement was that they should be sound enough to stand the driving and to last two years. They were of the length and kind that accumulate in the stock of a Bridge & Building Department, and seems so hard to put to a good use. The new piles were tamarack or pine.

Three 8 in. x 16 in. Douglas Fir stringers 32 feet long, lapped by each other, were used under each rail. The spans approximated 15 ft. 6 in. in length. In order to facilitate the raising and removing and to save the timber as much as possible, the posts were doweled to the caps and sills, and all brace plank were bolted. This timber will be used continuously until all of our elevation has been completed. The posts were cut to standard lengths and were used over and over.

There were a number of considerations which decided the use of this method of carrying the tracks over the streets. All of the traffic of the Chicago, Milwaukee & St. Paul Railway, including their fast passenger trains, enters Chicago over the tracks elevated. There was no practicable way to divert any of this traffic, and it was therefore necessary to keep two of the tracks in such condition that there would be perfect safety and no delay to trains. The method adopted fulfilled these requirements. It has great elasticity as to the time at which changes of grade could be made and as to the amount of raise. Changes of grade could be made very quickly. The use of piles permitted the excavation of foundations of the roadways with perfect safety at any stage of the work. It, therefore, permitted the opening of the streets to traffic before the girders were erected. The cost of maintenance was practically nothing.

The cost of this falsework per lin. ft. of one track was approximately:—

Labor - - - - -	$1.30
Loss and deterioration of timber and iron -	.80
Total - - - - -	$2.10

The labor item includes unloading all material used; driving piles, framing timber, putting in bridges, jacking them up, taking them out, picking up the material and maintaining them in line and surface. The material item includes the cost of all

Fig. 485. First and Second Stages of Track Elevation.

Fig. 486. Track Raised to Grade and Carried on Timber Trestle.

Fig. 487. A Finished Concrete Abutment.

material that was not recovered and a percentage allowed for deterioration. This percentage averages about 20%.

The cost of this falsework per lin. ft. of girder for one track was $2.90.

MASONRY.

The abutments and pedestals of all of the subways were built of concrete. The footings of the abutments are of Milwaukee cement concrete, and the pedestals and the neatwork of the abutments are of Portland cement concrete. The Milwaukee cement concrete is made of 1 part of Milwaukee cement to 2 parts of gravel to 3½ parts of crushed stone. The Portland cement concrete is made of 1 part of cement to 3 parts of gravel to 4 to 4½ parts of crushed stone. A supply of Alpha cement for this work was contracted for, but on account of unexpected complications in the cement market the dealer was unable to furnish a sufficient supply, thus necessitating the use of the following brands of cement, in addition to the Alpha, namely: Western Portland, Atlas, Iron Clad, Vulcanite, and Alsen's cement. Tests of samples from each car of cement were made at our Track Elevation Office. Compressive tests of 12 inch concrete cubes, 28 days old, of different proportions of material, were made from time to time at the Railway's West Milwaukee Shops.

A clean gravel, composed of about ⅔ coarse, sharp sand and ⅓ small stones, taken from this company's gravel pit, thirty miles distant, near Spaulding, was used in place of torpedo sand. By its use the difference between the cost of loading the gravel plus the cost of hauling to the work, and the cost of torpedo sand delivered at the work, was saved, as well as the saving made by substituting the stone in the gravel for an equal amount of crushed stone.

Crushed limestone from Hawthorne was used. Crusher run stone which would pass through a 3 inch ring was specified. The use of gravel and the crusher run stone has proven satisfactory. The only drawback has been the tendency of the coarser and finer parts of the latter to separate when unloaded, the coarser stone rolling to the outside of the pile and the finer stone remaining at the center. This is overcome by modifying the proportions of the gravel and stone slightly, to suit the conditions.

The abutments are faced on the street side and ends with a mortar of one part of cement to two parts of sand, built up at the same time as the body of the wall. A convenient device has been used for this purpose. It consisted of an iron plate 6 inches wide and about 6 feet long, with handles on the upper edge of one side, and two 1½ inch angles riveted at right angles to the length of the plate on the other side. The method followed was to stand this iron with the angles next to the face side of the form, then after filling the space between the plate and the face of the form with mortar and the space back of the plate with concrete, it was pulled up and the concrete and facing tamped together, thus making a perfect bond between the two.

The general appearance of the finished abutment with the sloping wings and projecting coping is shown in Fig. 487.

The forms for the abutments were made of 2 inch plank surface for the street side and the ends. 6 in. x 6 in. posts bolted together at the top and bottom with ¾ in. rods were used. The bottom bolts coming below the ground were left in the concrete, and the top ones coming above the concrete were taken out and used again. The lumber and posts were used over and over. When the surfaced plank became too poor for the face, it was used for the back. The cost of labor making the forms is comparatively high on account of the complicated shape of the back of the abutments, due to the fact that all but three of the subways make quite an acute angle with the track, and the back of the abutments were squared with each track by means of a triangular shaped addition for each track. The abutments of the subways to be built next year will have straight backs, and we hope to materially reduce the labor cost on this part of the work. Difficulty has been met with in attempting to make the face side of the form smooth, since every little imperfection is plainly reproduced in the face of the wall.

All of the concrete except that in the first three crossings was machine mixed by means of the portable mixer shown in Fig. 488. It consists essentially of a revolving cylinder resting on four idler wheels, whose axles are fixed to two side timbers forming part of the frame, which transmits the load to the wheels by which the mixer is moved from place to place. Inside of the cylinder are riveted various plates used to deflect the material in such a manner that as the cylinder revolves the ingredients are turned over and over and are thoroughly mixed. Two plates riveted to a shaft held in either of two positions by means of springs on the outside end of the cylinder, and turned by a device operated by the man putting the concrete into the wheelbarrows, serve to either carry the mixture over the dumping chute or to empty it into the chute. This latter has just enough inclination so that the concrete with a little assistance slides down into the wheelbarrow placed under the lower end. It extends into and across the inside of the cylinder, and is hinged longitudinally in its center so that it may be closed upon itself when the machine is mixing. Each end of the cylinder has an opening. Through the one in the end shown, the mixed concrete is discharged as just described; and through that in the other end the mixer is charged with the cement and aggregates in the proper proportion by means of wheelbarrows of a special pattern. The mixer is turned continuously, but the discharge is intermittent.

The water for the mixing is run into the machine through an iron pipe discharging under the dumping chute. The amount is measured by means of an upright cylinder, shown at the left side of the mixer, which may be adjusted to admit any given quantity of water as required. It is controlled by the man who dumps the

concrete. The operation followed is to first admit the required amount of water, then the cement, gravel and crushed stone, in the order stated. After a few turns of the machine, the plates in the interior are set to dump and the concrete is delivered into the wheelbarrows as they are placed under the chute. The time taken for each charge is from two to three minutes. The stated capacity of the mixer is 75 cu. yds. in 10 hours, but we have mixed 96 cu. yds. in that time, and could have made more if it could have been taken care of. Our average run has been about 70 cu. yds. with a crew of 26 to 30 men.

We use a 12 H. P. portable gasoline engine, shown on the right of the plate, to run the mixer. They are connected by means of a belt. The load is very light for this engine; 8 H. P. would probably be sufficient. The engine makes 235 revolutions per minute, and the pulley wheels are proportioned so that the mixer makes 12 revolutions per minute. This combination has proven an ideal one, since the mixer requires to be run at a uniform speed, and this the gasoline engine furnishes. Approximately, one gallon of gasoline is used per hour. The only attention required by the engine is to start it and oil it occasionally.

The product turned out by this mixer is as nearly perfect as it can be made, and is far superior to that mixed by hand, or by any of the mixers with which the writer is acquainted. From the mixer the concrete for the footing was wheeled to place and dumped. That for the neatwork, except at the first two crossings, was raised vertically in the wheelbarrows to the floor of the temporary bridge by means of a horse, as shown in Fig. 489, then wheeled to the point above that at which it was required and dumped. The empty wheelbarrows were lowered by means of a rope passing over a sheave, to one end of which the wheelbarrows were attached, and to the other a weight which returned the opposite end to the platform when the wheelbarrows were removed. By this means wheeling up a long incline was saved. The capacity of the horse is limited, however, especially during the hot weather, and the question of replacing him with a small gasoline engine, which may be used for a pumping engine when it is no longer needed for this purpose, is being considered for next season.

In order to make a good bond between the neat work and the footings, which had usually set before the neatwork was started, two rows of 3 in. plank were built in the top layer of the latter, with their tops on a level with that of the footing. These planks were taken out when the neatwork was started, leaving two grooves 12 in. wide and 3 in. deep extending the full length of the footing. By this means the two were fastened securely to each other.

The filling of the forms for each abutment was made in layers from 6 in. to 8 in. in thickness, and it was carried on continuously night and day from the time the neatwork was started on any one

abutment until the abutment was completed. For this purpose night and day concrete crews were organized. It is the writer's experience that when concrete is deposited on a course which has previously been set hard, a crack is very apt to develop between the two layers in spite of any precaution which may have been taken; and it was in order to prevent the formation of these cracks as far as possible, as well as to make a more intimate connection between the different layers, and to work the plant to its full capacity, that the work was carried on nights. The tops of the abutments were finished with a lay of 1 to 2 mortar about 1½ in. thick put on before the top had set. A fairly wet or quaking concrete was used, believing that better results are obtained with it than with a dry concrete. Each course was thoroughly tamped, about four men out of a crew of thirty men being engaged inside the form to do the tamping.

Our concrete plant saw very hard service, being run continuously from July 1st to Sept. 21st, with no shut-down except from midnight each Saturday until Monday morning and when moving from one subway to the next. This gave very little time for cleaning up the outfit or making repairs.

There were a number of reasons which decided the use of concrete masonry for the subways on this work, and our results so far seem to point to the correctness of the decision. Some of them were: the facility with which the abutments could be built, doing away with the necessity of using derricks, derrick cars or any other device which would in any way interfere with traffic; the fact that only unskilled labor would be required, thus reducing the danger of labor complications; our opinion that a better looking abutment, and one which would be just as durable, could be built for considerably less expenditure of money.

The concrete footings of Milwaukee cement cost per cu. yd.:

Material	$1.18
Labor	1.22
Total	$2.40

The Portland Cement concrete cost per cu. yd.:

Material in concrete, cement, gravel, crushed stone	$3.28
Labor on concrete	1.18
Material in forms	.11
Labor, building and taking down forms	.34
Total	$4.91

The above costs of material include freight on everything used, where bought outside of the city, as well as the purchase price, or the cost of loading in the case of the gravel.

The labor costs include all items of labor connected with the concrete work, such as moving plant from one crossing to the next; cost of building runways; unloading material, as well as mixing and placing; cost of gasoline for engine; oil for lights;

Fig. 488. Portable Concrete Mixer Driven by a Gasolene Engine.

Fig. 489. Erecting Girders with Two Twenty-Ton Derrick Cars.

Fig. 490. Long Span with Intermediate Supporting Columns.

city charge for water; and all other items of expense which a contractor would incur if the work had been done by contract. Charge for switching service is not included, nor are charges made for use and deterioration of tools. The switching service was comparatively small in amount, as the material was practically all unloaded from tracks assigned to us for this purpose.

The concrete work was begun about May 1st and the work planned for this year was practically completed Sept. 21st. In all about 8400 cu. yds. were mixed and placed. No attempt at speed was made, the plan being to merely keep pace with the elevation of the roadbed. In this, as in all of the work of the Bridge & Building Department in connection with the Track Elevation, our plans were made to suit the requirements of the Engineer of Track Elevation.

STEELWORK.

About August 1st the erection of the steelwork was begun. Eight of the four track subways are practically completed at this time, and the remaining three will be finished about Nov. 1st.

The plan followed in the erection was very simple. The fact that each track was up to grade at each crossing when the erection of the girders at that crossing was begun, was of material advantage. The girders, posts, castings, and floor material were shipped to the work as required, and were unloaded from the cars directly into place. The girders, shipped together usually, were so loaded on the cars that they reached the work right end to and placed on the right side of the car with reference to each other, when there was any difference in ends or sides.

The plan of erection was, after first placing all of the girders for a set of two or three crossings, to then remove the falsework from and put in and rivet up the steel floor, of first one and then the other, of the two construction tracks at these two or three crossings. The traffic was then diverted to these two tracks and the same operations followed for the remaining two. The object in erecting a set of two or three crossings together was to reduce to a minimum the number of times that it was necessary to divert the traffic.

The erection was done with two 20-ton derrick cars built from plans made by the Bridge & Building Department. The manner of using them is shown in Fig. 489. The girders are picked from the cars on which they are loaded and landed on their bedplates, one on each side of the track on which the cars stand. The view shows an outside girder in place, and a girder in the hooks ready to be swung out and lowered on the opposite side of the track.

From 30 to 34 men, working eight hours per day, were engaged on this work, and the aim was, as far as possible, to keep one part of them erecting and the other part riveting continuously. It took an average of a little less than seven days to erect and rivet

up complete each 4-track crossing. The crossings weighed from 440,000 lbs. to 630,000 lbs., and averaged about 525,000 lbs. each. The tight floor necessitated a large number of 5/8 in. rivets. Each crossing averaged about 3,500 7/8-in. and 17,000 3/4-in. field rivets. Our rivet crews averaged about 325 7/8-in. and 700 3/4-in. rivets during each day of eight hours.

The labor cost of erecting and riveting the first seven crossings complete has been about 0.175 cents per lb. of steel.

The metal, except the top of the floor plates, will be painted two coats of iron ore paint, mixed at the Railway Company's shops, and applied by our force. We are experimenting with a hot asphalt coating for the floor. The results so far have not been very satisfactory.

All the work described has been performed by employes of the Bridge & Building Department of this railway. In addition to this, the work of building catch-basins, man-holes and sewers; the laying and depressing of water mains; the paving of subways; the building of sidewalks and fences; the moving of buildings where extra right-of-way was purchased, has been done principally by contract, under the direction of the writer. This work is not yet completed.

In conclusion it may be stated that, with improvements in detail which have suggested themselves from time to time during the past season, the same general plan of work will be followed next year.

LII.

By ALBERT REICHMANN, MEM. W. S. E.*

Read October 5, 1898.

The structures on the line of the Chicago, Milwaukee & St. Paul Railway Company, spanning the streets of the City of Chicago, were built of open hearth steel with an ultimate tensile strength of 55,000 lbs. to 65,000 lbs. per square inch. They were designed to carry two 160 ton engines coupled together on each track. The girders, however, which carry a full track load, have their unit stresses increased 20 per cent over those carrying one-half track load, which is equivalent to carrying one and two-thirds the load of one rail with the same unit stresses as the girders carrying one rail load.

There are two types of crossings, one with intermediate supporting columns and one without. The crossings with intermediate supporting columns have their end girders tapering toward the end of the bridge and the intermediate spans parallel, as shown

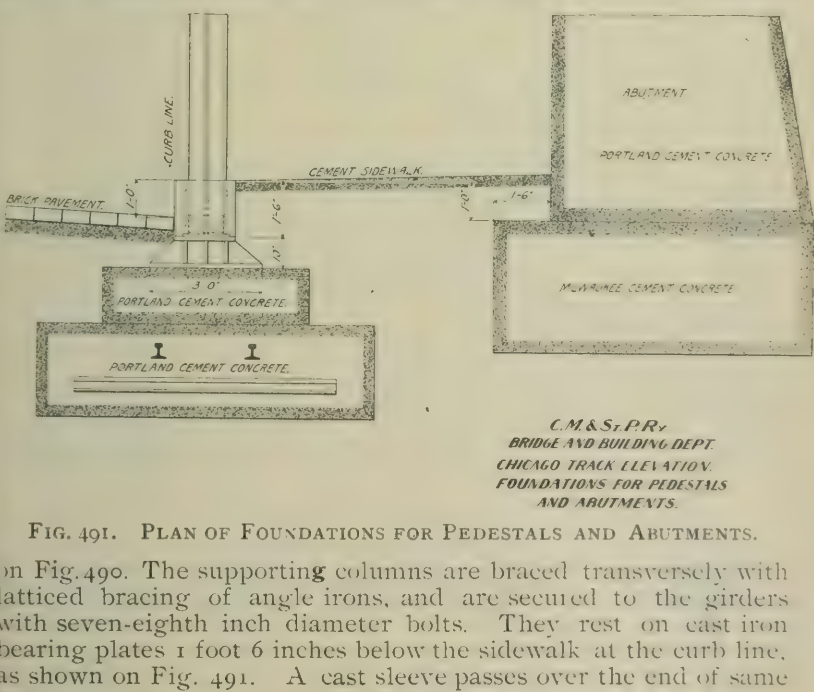

FIG. 491. PLAN OF FOUNDATIONS FOR PEDESTALS AND ABUTMENTS.

on Fig. 490. The supporting columns are braced transversely with latticed bracing of angle irons, and are secured to the girders with seven-eighth inch diameter bolts. They rest on cast iron bearing plates 1 foot 6 inches below the sidewalk at the curb line, as shown on Fig. 491. A cast sleeve passes over the end of same

*Assistant Engineer Bridges & Buildings, C. M & St. P. Ry.

which is flush with the top of the sidewalk and the sides of the curb.

The cast sleeves are filled with cement mortar so the water will drain from the columns. This construction takes up the minimum space on the sidewalk; besides, by going down under the sidewalk, a large bearing plate may be used, which is especially desirable where concrete is used, as the concrete very frequently is not given time to attain its maximum strength before its load is placed on it.

The other type of crossing consists of single span girders, as shown on Fig. 489. These girders have parallel flanges, with their ends rounded off to a radius of 3 feet. They rest on large bearing plates which are made in two pieces, and are so designed that the bottom castings may be set at any angle and at the same time allow for both lateral and longitudinal motion of the steel work. This is done by making a circular projection on the bottom main casting which fits into a circular recess in the top casting or cap. This recess in the top casting has one inch greater diameter than the circular projection on the bottom casting. The girders are spaced 13 feet centers when the track is on a tangent.

The Floor System consists of 12 inch 45 pound "I" beams spaced 15 inches centers. The "I" beams rest directly on the bottom flange angle of the girders, their bottom flanges being cut to a width of 3½ inches at the ends to avoid the rivets in the horizontal leg of the bottom flange angle. Thus it was not necessary to make any rivet space in the horizontal leg of the flange angle greater than 4½ inches.

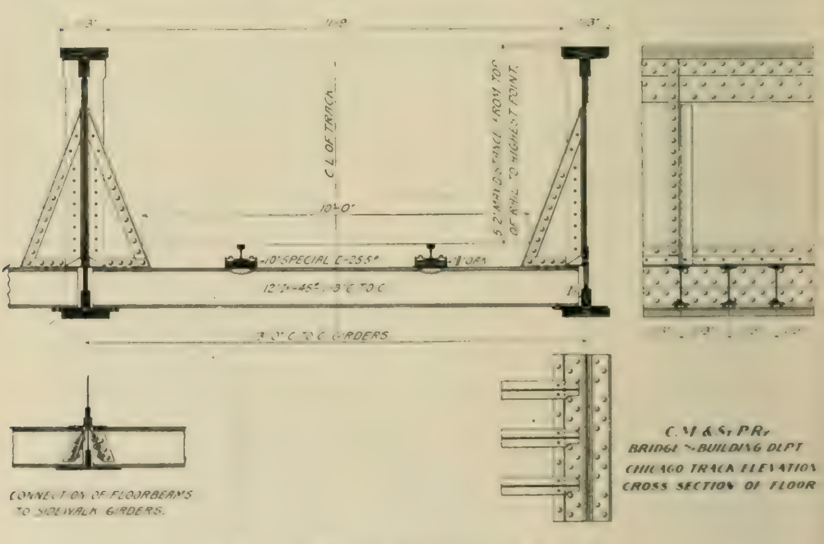

FIG. 492. CROSS SECTION OF FLOOR.

A space of ¾ inch was allowed between the ends of the "I" beams and the vertical leg of the flange angles of the girders. The rivets in this leg of the girder angle were all made ½ inch high, which allows ¼ inch clearance between the rivet heads and the end of the "I" beams, to allow for irregularities in the lengths of the "I" beams.

On the short sidewalk girders, the "I" beams were put on the bottom flange in the manner stated above, and, in addition thereto, were secured to the web of the girder by means of a slotted hanger plate, as shown in Fig. 492.

The "I" beams were secured to the bottom flange of the girders with two ⅞ inch diameter rivets at each end. The "I" beams were covered with $\frac{5}{16}$ inch plates, mostly five feet wide, which run transversely to the bridge and spliced over an "I" beam. 5 x 3 ½ x ⅜ inch angles secure the end of the decking and "I" beams to the web of the girders.

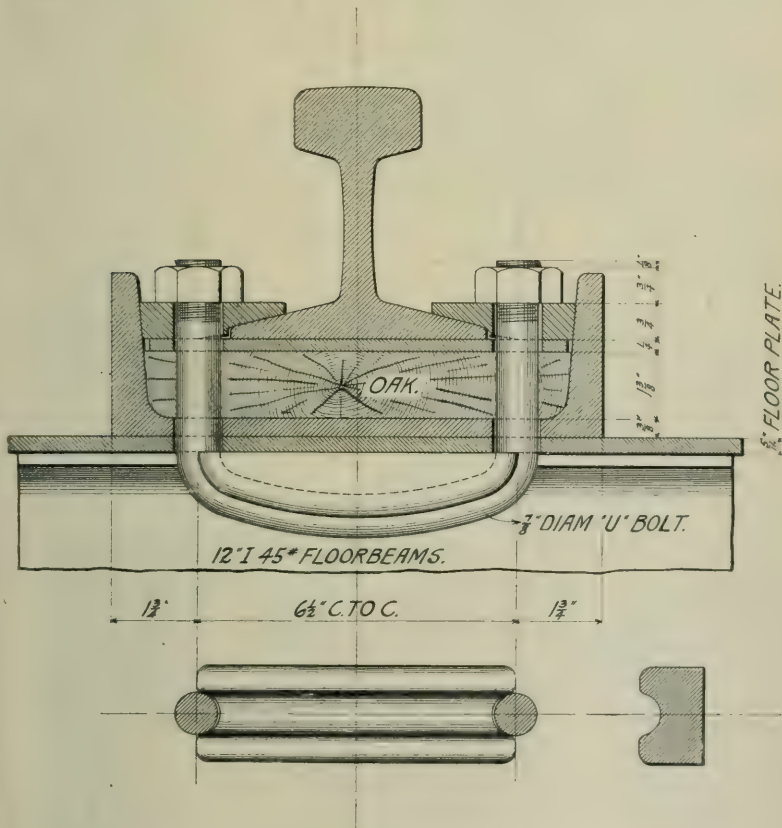

FIG. 493. RAIL FASTENINGS—C. M. ST. P. RY.

The rails rest directly on a 1/4 inch steel plate which is put on top of 1 5/8 inch thick oak timber, the same being fitted in a 10 inch 25.5 lb. channel, which has a special wide flange, (see Fig. 493). Thus the timber is confined in the channel. The rails are bolted between every other beam by means of 7/8 inch diameter "U" shaped bolts.

As most of the season's work was on a 30 minute curve, this arrangement proved very satisfactory, as the super-elevation of 7/8 inch could very readily be put in by increasing the thickness of the timber under the outer rail to 2 1/4 inches. On Springfield avenue, where we had a 12 degree curve, this construction had to be modified somewhat, as the super-elevation there was 3 inches, which made the timber under the outer rail 4 5/8 inches thick. For this reason, angles with their horizontal legs standing out were used in place of channels. The knee braces were spaced about every 7 feet 6 inches.

The large single span girders have a 5/8 inch camber, and these crossings have their drains at the ends. Their drainage consists of a "Z" bar riveted to a vertical plate which is secured to the decking by means of an angle.

Where posts were used, the sidewalk girders were given a fall of 1/4 inch toward the posts, where a trough formed out of two "Z" bars was built between two "I" beams of the floor, from which a down spout will be attached which will empty into the street at the curb.

All holes in the main girders were reamed. It was not considered necessary to ream the decking and "I" beams, as the latter had only two holes in each end of the bottom flange.

The rivets in the girders are all 7/8 inch diameter, and those in the decking and top flange of the "I" beams 5/8 inch in diameter.

As almost all of these crossings are on a skew, it was considered advisable to have the steel work for each track end square to the same. This was done by making the "I" beams rest on the main girders at one end, and on a small girder, which rests directly on the masonry at the other. As the skews were quite sharp in all cases, it was necessary to build out an angular projection on the back of the abutments at each track. This made the abutments quite complicated, and made the building of the concrete frames quite difficult.

Complete detail working plans for this work were made by the Bridge & Building Department of this company.

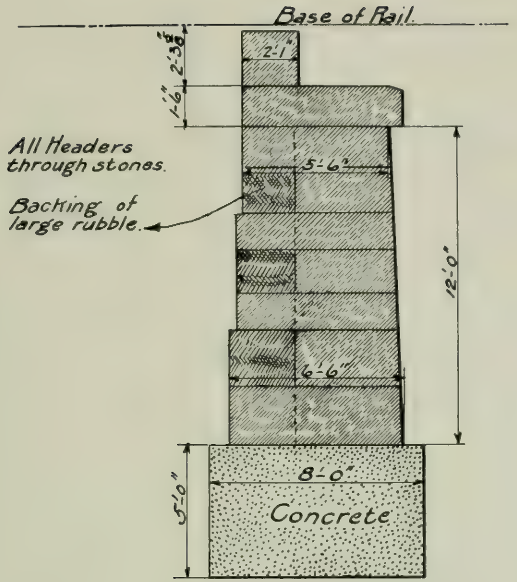

FIG. 494. CROSS SECTION OF ABUTMENTS.

FIG. 495. TRAVELING CRANE LAYING MASONRY AT 22D STREET AND TRUMBULL AVENUE.

LIII.

TRACK ELEVATION OF THE CHICAGO, BURLINGTON & QUINCY RAILROAD.

By Geo. H. Bremner, Mem. W. S. E.*

(*Read October 5, 1898.*)

I comply with the request of your committee to discuss this subject with considerable reluctance, as the Chicago, Burlington & Quincy Railroad Company has not as yet completed any track elevation in Chicago. We have, however, made preparations for elevating next season a section of about 2 3/4 miles of main track, extending from Rockwell Street to South Forty-sixth Avenue.

We have four main tracks on this section, besides a number of sidings to industries. As we have no other entrance into the city, all our traffic has to come over these tracks, and the chief problem we have to contend with is to do the work without delaying this traffic. A small delay means a blockade, as the trains are very close together. We have done our work this year by taking possession of two tracks at a time, using the other two as double tracks, and have found it to work very well indeed.

There are to be sixteen subways. The average elevation of our tracks will be about ten feet, and the depressions of the streets two to four feet. We have this year put in the foundations for our abutments, and for the piers at the streets where we do not have clear spans. There are only four of these where piers are needed. We are doing all the masonry and track work ourselves, and do not expect to contract any of the work except the bridges, street grading, pavements and sidewalks.

The drainage question will not bother us greatly as we are to be so high that all the subways will be above the sewers. Where there are large sewers we will strengthen them with T rail covers.

The foundations of our abutments, Fig. 494, consists of five feet of natural cement concrete made in the proportion of 1, 2 and 5, and on this, we have this year laid one or two courses of masonry, as was needed to finish the abutments up to the bottom of the ties. Our masonry consists at three subways of Illinois limestone, one of Berea sandstone, and the remainder of Bedford, or rather Romona, Indiana, limestone. We have laid this stone with a locomotive crane, Fig. 495, with a maximum capacity of twenty-five tons at a sixteen feet radius with outriggers, and of six tons at thirty-eight feet radius without outriggers. We have handled the

*Assistant Engineer, C. B. & Q. R. R.

four to five one-half ton dimension stones with this very readily, and have found it a very economical tool.

We expect to have some very substantial abutments which will compare favorably with any others in the city, when completed.

We are also this season putting in such retaining walls of limestone rubble as will be needed. In most places our right-of-way is wide enough to take the slopes of the bank, so that we do not need any great amount of these.

As we have not begun our elevation as early as the other roads represented here this evening, we cannot say that our methods are entirely original, but are more or less modifications of what we have observed the other roads doing. Fig. 496 shows a cross-section of the floor to be used on the bridges. We expect next year to put in our bridges and elevate our tracks, after a variation of the method which Mr. Evans has described to us this evening; putting our girders on piling, and laying our masonry with the crane after the elevation is completed.

The details of our plans for next year, I will not attempt to describe until we see how they work.

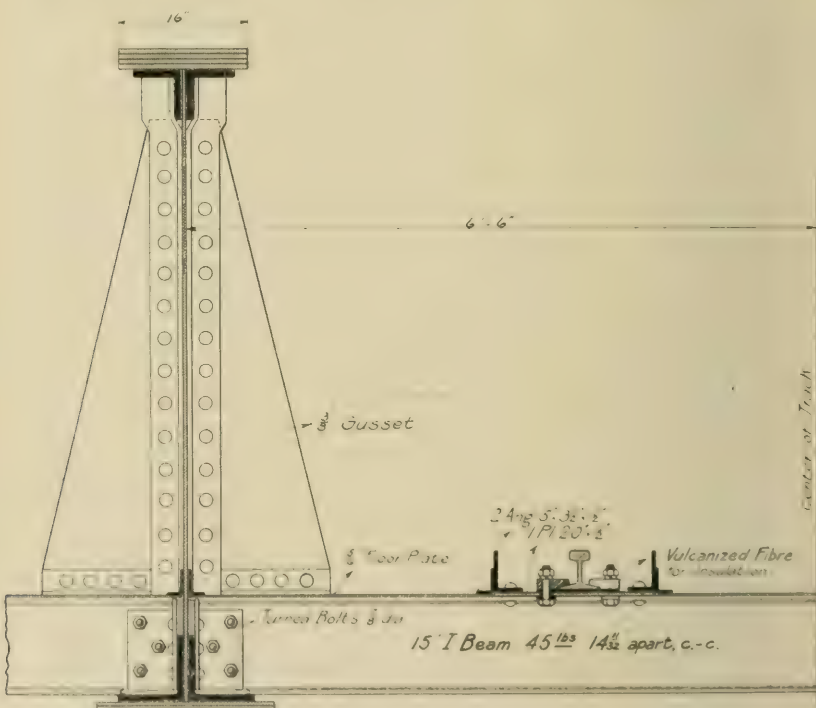

FIG. 496. SECTION OF FLOOR FOR BRIDGES, C. B. & Q. R. R.

Fig. 497. ⅞-inch Steel Rivet Left 24 Hours in an Oil Heating Furnace. Scale partially removed. Photograph actual size.

Fig. 498. ⅞-inch Steel Rivet Left 16 Hours in an Oil Heating Furnace. Bent cold flat, cracked on opening bend.

NOTES.

EFFECT OF LONG CONTINUED HEATING ON STEEL RIVETS.

ONWARD BATES, Mem. W. S. E.

President Noble: We have two curiosities here for which I understand we are indebted to Mr. Bates, showing the effect on rivets of long continued heating in an oil furnace. (Specimens of two steel rivets shown.)

Mr. Bates: I do not know what this means, but our bridge inspector brought these two rivets into my office, and he is the father of the experiment. The question was whether steel rivets would be burned in heating. He left these rivets in a furnace at the Lassig Bridge Works. I asked Mr. Lassig if I could send them over here and he made no objection, as they would not discredit him. This rivet, Fig. 497, was twenty-four hours in an oil furnace; this one, Fig. 498, was in sixteen hours. I think that rivet must have been laid to one side in the furnace, because it looks as if it had not been disturbed. This one, Fig. 498, was taken out and all the scales taken off, then it was bent. This crack was made in bending it backward. The inspector's conclusion was that rivets are not apt to be injured by remaining a considerable time in the furnace. I do not like to make a rule from one experiment, but as one experiment I thought it well to bring it in and show it.

Mr. Condron: It would be an interesting thing now to do the same with iron rivets and see whether they would stand continuous heating in a furnace as well as these steel rivets have.

I believe Mr. Bates has set an excellent example to many of us in bringing up these notes—that is what they really are—of every day practice. They are useful and valuable to the Society and usually the members overlook them. They forget that small matters of interest to them will also be of interest to others.

ABSTRACTS FROM TECHNICAL PAPERS.

A LECTURE ON "THE SOUDAN AND RECENT BRITISH CAMPAIGNS THERE."

By COL. H. G. PROUT, September 21, 1898.

(*From The Railway Age, Chicago, Sept. 23, 1898.*)

As stated in the programme recently published in The Railway Age, the meeting of the Western Society of Engineers for the present week was designated as "Ladies' evening." The subject of the meeting was a lecture by Col. Henry G. Prout on "The Soudan and Recent British Campaigns there," upon which the speaker was thoroughly at home by reason of his service as an officer of engineers under the Khedive from 1873 to 1878.

Colonel Prout began with a brief account of the geography of the country, the difficulties of the position from a military point of view on account of the great stretches of waterless desert surrounding it, and of the people themselves, and their leaders. A high tribute was paid to the character of that part of the people made up of Bedouin Arabs, whom the speaker considered among the best types he had ever met.

The events leading up to the revolt of the Mahdi, the iniquitous manner in which the affairs of government were carried on, and which was the prime cause of the revolt, the purposes and theories of General Gordon and the course of events which made his death inevitable, were set forth. Colonel Prout succeeded General Gordon as governor-general of the equatorial provinces, and therefore spoke from personal knowledge of the conditions existing.

The purposes of the present English, though nominally Egyptian, campaign, in the Soudan, were touched upon. The speaker stated that Sir Herbert Kitchener had been preparing for his present work for 14 years, and his campaign had so far been so successful that there was no doubt of the complete control of the country for a thousand miles up the Nile from Khartoum. As to the objects of the English government, the speaker expressed no definite opinion. He gave several reasons, prominent among which was the desire for a complete connection from Egypt to Cape Town.

The lecture was given in Steinway hall, and was well attended. The speaker handled his subject with the ease born of a full knowledge, and contributed much to an understanding of the present situation.

MEETING OF THE WESTERN SOCIETY OF ENGINEERS.

October 5, 1898.

(From The Railroad Gazette, N. Y., Oct. 14, 1898.)

At the regular meeting of the Western Society of Engineers, Oct. 5, a paper was read by Mr. L. H. Evans, Engineer of Track Elevation of the Chicago & Northwestern, on the "Track Elevation of the Chicago & Northwestern and the Pittsburg, Cincinnati, Chicago & St. Louis Railway." Mr. Evans' paper was one of unusual interest and attracted the largest attendance had at any regular meeting of the Society during the past two years, there being 147 present. The paper was illustrated with 24 stereopticon views, showing very clearly the most interesting features of the work done under his direction during the past three years. This work includes the elevating of over 12 miles of main line, most of which is three-track, while several miles is five-track line. In these 12 miles 72 subways have been provided for street crossings, involving over 30,000 tons of steel. We shall abstract Mr. Evans' paper quite fully in a subsequent issue.

Mr. Evans' paper was followed by those of Mr. W. L. Webb, Mr. W. A. Rogers and Mr. A. F. Reichmann, Engineers of the Chicago, Milwaukee & St. Paul, describing the track elevation work being done this year by that road. These papers were illustrated by nine stereopticon views. A paper was also read by Mr. W. H. Parkhurst, Engineer of Bridges of the Illinois Central, describing the elevation of the tracks of that road, which tracks were raised during 1892 and the early part of 1893. This paper was also elaborately illustrated by stereopticon views. Mr. Parkhurst further presented notes on the elevation of the St. Charles Air Line tracks in the business part of Chicago, made necessary by the elimination of the grade crossings at Sixteenth and Clark streets. The last paper read was by Mr. G. H. Bremner, Engineer of Track Elevation of the Chicago, Burlington & Quincy, and dealt with the work being done by, and proposed for next season on that road. The only work being done this year is the putting in of foundations, preparatory to the work of elevating tracks next season.

Additional papers were to have been presented describing the work of the Chicago, Rock Island & Pacific and Lake Shore & Michigan Southern; the joint elevation of these roads and the Chicago & Alton, Atchison, Topeka & Santa Fe, St. Charles Air Line and Chicago & Western Indiana Ry. at the Sixteenth street crossing; and the elevation of the Pittsburg, Ft. Wayne & Chicago. For lack of time these papers had to be held over until a later meeting of the Society, at which time the entire subject will be open for general discussion.

INSPECTION TRIP OF THE WESTERN SOCIETY OF ENGINEERS

Over the Track Elevation Work of the Chicago & Northwestern Ry., Pittsburg, Cincinnati, Chicago & St. Louis Ry. and the Chicago, Milwaukee & St. Paul Ry.

October 8, 1898.

(*From the Railroad Gazette, N. Y., Oct. 14, 1898.*)

On Saturday, Oct. 8, a party of 150 members and guests of the Society accepted the invitation of the Chicago & Northwestern to take a special train and make an inspection of the work done on this line and on the line of the Chicago, Milwaukee & St. Paul. The train left the Chicago & Northwestern depot at 1 p. m. After making the run to Rose Hill Station, on the Milwaukee Division, the train returned to Clybourn Junction, stops being made at Ravenswood and Lincoln avenue. From Clybourn Junction the train was taken over the Wisconsin Division as far as Mayfair Station, where it was switched over the "Mayfair cut-off" to Forty-fourth avenue west and the Galena Division, and then over this line to Rockwell street, where the tracks of the Chicago & Northwestern and the Pittsburg, Cincinnati, Chicago & St. Louis are parallel. These tracks were jointly elevated under the direction of Mr. Evans.

Frequent stops were made all along the way, so that the work could be critically examined. After having gone over all the work done on the Chicago & Northwestern, the train was switched onto the tracks of the Chicago, Milwaukee & St. Paul, and a thorough inspection was made of the work being done by that road. This work is especially interesting because of the fact that concrete abutments are being used exclusively at the subways. We shall abstract from the papers describing the work on this road which were read at the meeting of October 5, in a later issue.

Among the railroad engineers in the party who have charge of track elevation work were Messrs. L. H. Evans and W. H. Finley, of the Chicago & Northwestern; Onward Bates, W. S. Webb, W. A. Rogers and A. F. Reichmann, of the Chicago, Milwaukee &. St. Paul; E. J. Blake and G. H. Bremner, of the Chicago, Burlington & Quincy; W. H. Coverdale, of the Pennsylvania Lines; H. C. Draper, Chief Engineer Chicago & Alton, and Ferd Hall, Chief Engineer Chicago, Indianapolis & Louisville.

INSPECTION TRIP OF THE WESTERN SOCIETY OF ENGINEERS

Over the Track Elevation Work of the Pittsburg, Ft. Wayne & Chicago Ry., Chicago, Rock Island & Pacific Ry., Lake Shore & Michigan Southern Ry., and the Joint Elevation and Depression of Tracks at Sixteenth and Clark Streets, October 15, 1898.

(*From The Railroad Gazette, N. Y., Oct. 21st, 1898.*)

On Saturday afternoon, Oct. 15, a special train of four cars furnished by the Pennsylvania Lines, took a party of 158 members of the Western Society of Engineers to inspect the track elevation work of that road, the Lake Shore & Michigan Southern, and the Chicago, Rock Island & Pacific. The train left the Union Station at 1:15 o'clock and was run to a point below South Chicago, where it was turned on a "Y." The track elevation commences at South Park avenue, and on the return the first stop was made at State street, where the elevation of the tracks of the Pittsburg, Ft. Wayne & Chicago is nearly completed, while that of the Lake Shore & Michigan Southern and the Chicago, Rock Island & Pacific is well under way; a new union station for the joint use of these three roads is being built on the south side of Sixty-third street. A new freight station has already been completed by the Pittsburg, Ft. Wayne & Chicago at State street, and one of the notable features of the work of this road is that stone ballast is placed between the ties and the bridge floors to reduce the noise of passing trains. This has so far not been done by any of the other Chicago roads. The next stop was made at Garfield Boulevard, which bridge is completed, and north of which the tracks descend to meet the old grade near Fifty-first street. The train was left near Sixteenth street and the extensive work at the Sixteenth street crossing was inspected. At this point all the tracks have now been brought to the new grades, the retaining walls and abutments have been built, and there remains to replace the temporary bridges with the steel work. The steel for the viaduct in Clark street was in process of erection on the day of the excursion, and it is expected that this will be in place by Oct. 19.

ABSTRACT OF THE MINUTES OF THE SOCIETY.

REGULAR MEETING—SEPTEMBER 7th, 1898.

A regular meeting (the 388th) of the Society was held in its Hall, Wednesday evening, the 7th of September, 1898, President Alfred Noble in the Chair. The reading of the minutes was dispensed with, and no reports from committees were made.

At the meeting of the Board of Direction, on the 1st instant, applications for active membership were received from Messrs. E. J. Rosencrans and John H. Warder, and referred to the membership committee.

The reading of the papers was begun by Mr. D. J. Whittemore, presenting his paper on "The Equilibristat"—a device for railroad track inspection.

Mr. R. D. Seymour read a paper on "Cableway Construction," which was illustrated with lantern-slides.

The next paper was presented by Mr. Onward Bates—"Concrete Facing on a Sandstone Bluff at St. Paul, Minn." Mr. Bates also showed samples of steel bolts, burned in an oil furnace.

The meeting adjourned.

SPECIAL MEETING—SEPTEMBER 21st, 1898.

A special meeting (the 389th) of the Society was held in Steinway Hall, (in order to provide accommodation for an unusual attendance), on 21st of September, 1898, at which time a lecture on "The Soudan and Recent British Campaigns There," was given by Colonel H. G. Prout, of the Railroad Gazette. There were about 325 members and guests present.

President Alfred Noble introduced the speaker, who gave an outline description of the country, explained the difficulties attending military operations, pictured the desert with its vast expanse, brownish hue and cloudless sky, and gave a vivid description of a battle between 2,000 British soldiers and a powerful band of Arabs.

The lecture was of a high order, full of interest and greatly enjoyed by the audience.

Col. Prout entered the service of the Khedive in the fall of 1873, as Major of Engineers, and left the service in the middle of 1878, being then a Colonel in the army. The first year of his service he was in Lower Egypt, the Delta, and on the Syrian frontier. The rest of his service was in the Soudan proper, and in the country still further south at the head of the Nile. For a year and a half he had command of an expedition in the countries west of the Nile, and about the latitude of Khartoum, namely: Kordofan and Darfour. Then he was made Governor General of the provinces of the equator. In that position he succeeded Gordon, who for two years and a half had been the Governor General. At that time Gordon came down the Nile as far as Khartoum as Governor General of the Soudan, and Col. Prout's province was made a part of the Soudan government; before this it had been independent, and reported directly to Cairo. He then became Gordon's subordinate, it having been at

Gordon's request that he was sent from Darfour to succeed him as Governor of the provinces of the equator. The capital of the provinces was at that time Lado, 1,000 miles south of Khartoum.

Col. Prout's lecture dealt, not with the provinces of the equator, but with the Egyptian Soudan proper, and chiefly with the region where the recent fighting has taken place. His operations of a year and a half in Kordofan and Darfour brought him into close contact with the tribes which have been controlling the Soudan government for the last fifteen years, and which have now been defeated by Sir Herbert Kitchener.

The meeting adjourned.

SPECIAL MEETING—SEPTEMBER 28th, 1898.

A special meeting (the 390th) of the Society was held in its Hall, 28th of September, 1898.

In the absence of officers, Mr. Emil Gerber was elected to the chair.

Reports from committees being called for, Mr. T. L. Condron, chairman of the committee on papers, stated that the next regular meeting, 5th of October, 1898, would probably be very largely attended, as papers on "Track Elevation" in Chicago, fully illustrated with lantern-slides, would be presented. He suggested that those present advise absent members and others interested that the subject would be presented at the next meeting. He also stated that arrangements were being made which would enable the society to inspect the work of track elevation throughout the city.

The paper of the evening, "The Foundations for the U. S. Government Post Office and Custom House Building at Chicago," was then read by Gen. William Sooy Smith, Engineer in charge of Foundations, was full of interest.

The meeting adjourned.

REGULAR MEETING—OCTOBER 5th, 1898.

A regular meeting (the 391st) of the Society was held in its Hall on the 5th of October, 1898, Vice-President A. V. Powell in the chair, 140 members and guests present. A motion was made and carried that the usual order of business be suspended, and that the papers of the evening be taken up at once.

Before the papers were presented, however, the Secretary read a communication from the entertainment committee relating to the excursion to Omaha. A motion was made that the itinerary be put in print and sent to all the members. Carried.

Mr. Louis H. Evans was then presented, and read his paper on "Track Elevation of the Chicago & Northwestern Ry," which was profusely illustrated with lantern-slides showing the progressive steps in the work, and the appliances used.

At the conclusion of the paper, the Secretary read a communication from Mr. Thos. H. Johnson, C. E., of the P. C. C. & St. L. Ry., stating the work for that line had been placed under the supervision of Mr. Evans, and would be covered by Mr. Evans' paper.

Mr. H. W. Parkhurst, of the Illinois Central Railroad, was then presented, and read a paper descriptive of the elevation work on that line, illustrated with lantern-slides.

The question of adjournment, as it was getting late, was brought up for consideration and promptly voted down.

The Chicago, Milwaukee & St. Paul Ry. work was described and means used explained by Messrs. W. L. Webb, W. A. Rogers and Albert Reichmann. Mr. Geo. H. Bremner read a paper relating to the part in the elevation taken by the C. B. & Q. R. R. At the conclusion of which the meeting adjourned.

At a meeting of the Board of Direction, 1st of October, 1898, Mr. E. B. Clark was elected to active membership in the Society, and John C. Whitridge transferred from junior to grade of active member.

The membership recommended Messrs. Edward J. Rosencrans and John H. Warder for active membership.

At meeting of the Board on the 8th of October, 1898, the membership committee recommended Messrs. Charles H. Mercer, Joseph Henry Prior and Walter A. Rogers for active membership.

On the afternoon of the 8th of October, 1898, 140 members and guests of the Society, were, by the courtesy of the Chicago & Northwestern Ry. Co., afforded an opportunity to inspect the work of track elevation of that road and the Chicago, Milwaukee & St. Paul road. At different points along the route stops were made to view the work.

On Saturday, the 15th of October, 1898, the Society was the guest of the Pennsylvania Railroad Company. At 1 P. M., 160 members and friends left Union Station and spent the afternoon in examination of the track elevation of the Pittsburg, Ft. Wayne & Chicago Ry., also 63d street crossings of the Lake Shore & Michigan Southern Ry. and Chicago, Rock Island & Pacific Ry.

NELSON L. LITTEN, Secretary

LIBRARY NOTES.

The Library Committee wishes to express thanks for donations to the library. Back numbers of periodicals are desirable for exchanges and aid in completing valuable volumes for our files.

Since the last issue of the Journal, we have received the following as gifts from the donors named:

Onward Bates.—The Superintendent of Bridges and Buildings.
E. A. Birge, Director Wis. Geol. and Natural History Survey.—
Forestry conditions in Northern Wisconsin.
U. S. Bureau of Foreign Commerce.—
Consular Reports, September and October, 1898.
Mohonk Conference Ass'n.—
Report of 4th Annual Meeting of the Lake Mohonk Conference on International Arbitration. 1898.
The Philadelphia Commercial Museum.—
American Trade with India.
F.M.F.Cazin.—Old and New Methods applied in planning Pipe lines and Penstocks.
U.S.Dept.Agri.—Experimental Tree-Planting in the Plains.
Rudolph Hering.—Dilution Process of Sewage Disposal.
Bacterial Processes of Sewage Purification.
U. S. Geological Survey.—Monograph XXX. Fossil Medusa.
U. S. Geological Survey.—Bulletins. 1888 and 1889.
Institution Civil Engineers,
London.—Minutes of the proceedings—Vol. cxxxiii.
Report of Committee on the Thermal Efficiency of Steam Engines.

BY PURCHASE.

Ganguillet & Kutter.—On Flow of Water in Rivers and other Channels.
John C. Wait.—Engineering and Architectural Jurisprudence.

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LIV.

MASONRY.

By George S. Morison, Mem. W. S. E.

(Read October 21, 1898.)

In the adaptation of the great powers of nature to the use and convenience of man, the civil engineer, if he would increase those adaptations, must devise methods and use materials which were unknown to earlier generations. In our profession conservatism and precedent are perhaps less valued and properly less appreciated than in some others. Still, the law makers who have done most for the good of mankind are generally those who have made radical departures from the principles of the past and the reformers who have done most to help their fellows have been large enough to rise above the narrow bounds of bigoted conservatism; but as the theologian who cuts entirely loose from the past may become a scoffer rather than a reformer, and as the jurist who would break down all existing laws may be the greatest enemy of society, so it is important for the engineer to give the attention they deserve to the materials and the workmanship which have been in continuous use from earlier times. I propose, therefore, to say something about masonry; the building material of antiquity and of the middle ages; the most permanent building material used; the only material which is suitable for monumental works.

The materials used in construction may be divided generally into two classes, which, for want of better names, we may term the lower and the higher materials. The lower comprise earth and stone, whether used in the natural conditions in which they are found or in improved conditions into which they are artificially brought. The higher materials comprise metals and timber.

Between the two classes of materials there are marked differences. The first difference is in perishability. The lower class may be called imperishable; they consist of chemical elements combined in stable compounds. The presence of oxygen cannot destroy that which is already completely oxidized. Whatever destruction may occur is of a mechanical character; they may be

washed, broken or disintegrated, but in every case it is a mechanical action, the materials themselves do not change. By selecting materials adapted to their specific uses and so arranging them that the agencies of mechanical destruction are as far as possible kept away, we can approach more nearly to an everlasting construction than with anything else. On the other hand both timber and metal are perishable. Timber is an organic substance, subject to the most rapid forms of destruction; the natural exposure to the elements will destroy even the most permanent kinds within the limits of a human life, while the duration of the woods available for ordinary construction is but a few years. Timber is exposed to the more quick oxidation known as fire, the most rapid working agency of destruction which we know. Metal is more durable; it oxidizes slowly, unless exposed to active chemical agencies; its life may be measured by decades instead of years, but it must be an object of constant care.

On the other hand, both of the higher classes of material have great tensile strength and can sustain the moderate deformations which are considered essential to the safe resistance of tensile strains; they are the only materials which the engineer is willing to use in tension.

We have, therefore, four materials used in construction; earth, masonry, timber, metal.

The first of these, earth, is that which has been used in the greatest quantities. Its use was the most easily understood. It required in its original working only the simplest appliances. The first earthwork was probably built by a man with no other tools than his sturdy hands with their thick, coarse nails. It is to this day used more than anything else for dams, for levees, for that greatest of modern tools, the railroad embankment, for the most improved form of modern fortifications. Half civilized people used it to build their sacrificial temples and their burial mounds. If we read the stars rightly it is only by the use of enormous earthworks that the inhabitants of a neighboring planet maintain a prosperous existence on their arid world.

Masonry is the building material of history. The greatest, and in many respects the finest, specimens of masonry now existing, were built in a time of which we have no records outside of the land in which they are found, while their extreme antiquity shows that masonry had been carried to a high degree of perfection when written history began. It is the material in which the great constructors of old expressed their highest skill It is the material in which the great city of the Mediterranean recorded its conquest of the world. Until the present century it has been the only material of which great works have been made.

Next to earth, timber was probably the first material employed in construction. It is the most convenient of all; light, easily worked, strong, it is indispensable for many purposes; it offered ready means of comfort to the primitive man and where it is still

abundant and cheap, it is used more than anything else, men generally preferring to take the risk of destruction in return for the convenience and economy which it offers. It has seen its highest development in our country where abundant forests have for the first time existed with modern machinery and tools to work them. The rapid development of North America has been made possible through the abundance and excellence of its timber. With care many of our timber buildings will be preserved for some centuries as historical relics, but sooner or later the wooden buildings of North America will have disappeared as completely as has the earlier timber architecture of India.

Metallic construction is new. It was only rendered possible by the advent of cheap metal work. Metal work was always expensive until the introduction of modern power; until the engineer began to manufacture power, the means for producing metals in large quantities did not exist; until metals could be produced in great quantities they were costly. We have as yet but one metal which is available for general construction and that is iron, whether in the cheap form of the cast metal, in the more expensive and purer form of wrought iron, or in the latest development of ingot metal which we call steel, but which is much more nearly pure iron than cast iron is. This material being a metal is oxidizable and to that extent perishable, but it has far greater strength than anything else which can be used in construction. It gives the greatest results for the least expenditure of matter; where compactness and strength are required it is practically the only thing to use; it is pre-eminently the stuff of which tools should be made, whether those tools be in a machine shop or be structures designed for some specific utilitarian purpose, but its uses are practical rather than more, its substitution for masonry, is only justified on economical grounds.

Masonry, therefore, the most permanent form of contruction which man can make, the only material suitable for those works which passing beyond the requirement of tools, assume a monumental character and, enduring from one epoch to another, transmit to future ages the actual work of today; masonry respected for its antiquity, admired for its enduring futurity, is the subject of this lecture. I shall not consider the formulæ by which its strength is calculated nor the details of methods by which it is made, but shall simply give a general outline of what it is and review the principles which must be followed to secure good results.

Masonry may be broadly defined as any construction formed of inorganic non-metallic material, in which the parts are so fitted together as to form a single united whole. In this broad sense it includes every variety of brick work, all kinds of stone masonry and all of the monolithic work commonly called concrete. It excludes every form of embankment, whether of earth or stone,

in which the materials are held in their final position by the friction of pieces on one another, which limits the slopes on which sliding takes place.

Masonry, as defined in this broad way, may be divided into four general classes according to the material of which it is made. The first of these is adobe, the unburned brick of the Egyptians and the Aztecs, the usual cheap building material in all arid countries. The second is brick as we understand it, burned till it is harder and more durable than many kinds of stone, while its regular shape makes it an exceptionally convenient material to use. The third is stone in all its varieties. The last is concrete, an artificial stone.

Adobe, or unburned brick is nothing but earth of suitable characacter put in a special shape, but the form in which it is worked and the manner in which it is laid up, class it with masonry. Where protected from water it may be very durable, though less so than the other forms of masonry; the oldest church edifice in the United States, constructed in the sixteenth century, is built of adobe. Its manufacture is very simple; a suitable earth mixed with a little chopped straw is moistened and worked by a hoe into a proper degree of plasticity, shaped in a mould and laid in the sun to dry, the common dimensions being about twice those of ordinary bricks, so that an adobe is about eight times as large as a common brick. Adobes are laid up in a sort of mud mortar made of the same earth and the finished wall is usually plastered with the same kind of mud, thus making a solid wall of hard dry unburned clay. This, from time immemorial, has been the common building material of the Egyptians; their temples and pyramids were of stone; their burial places were caves cut in the rocks on the bluffs along the Nile, but their ordinary dwellings were and still are adobe. Adobe is the common, cheap building material of Mexico and a large part of Spanish America, but the Spaniards found it when they came. It is used in both the old and the new worlds in practically the same manner and in both its use goes back to an extreme antiquity. In a suitable climate adobe forms a most excellent building material, the heavy adobe walls, accompanied as often they are by thick roofs of heavy wooden beams covered with the same material, are a great protection from changes of temperature outside. On the hottest summer day in countries where the outside temperature is often above blood heat the interior of an adobe building is always comfortable and cool.

Of all forms of masonry perhaps brick is the most useful. It is in too common use to require description. The bricks should be made of good material and well burned; two kinds of material are used, the ordinary plastic clay which must simply be tempered with water, with perhaps the addition of a little sand, and worked into proper condition, and the various soft slates more properly called shales, which must be ground before they are used; building brick

Fig. 499. Ancient Bakery and Flour Mills, Pompeii.

are generally made of the former, paving and other specially hard brick of the latter. The harder a brick is and the less water it will absorb the better and more durable it will prove, but burning should not be carried to such an extent as to make a smooth, vitrified surface to which mortar will not adhere. In brick masonry mortar joints are frequent; they form so large a portion of the whole that the strength of a brick wall is determined by the strength of the mortar. In a perfect wall the mortar and brick would be of equal strength; it is only when the bricks are very poor and the mortar very good that a wall fails by the breaking or crushing of the bricks. With good brick and good mortar, well put together so that all the joints are thoroughly filled, brick masonry is one of the most durable things that man can build. Some varieties of stone may resist the elements better but no other material is as well fitted to resist fire; a heavy brick wall will stand almost uninjured when a granite wall close by will be splintered to pieces. The durability and excellence of brick work are illustrated by its use in Rome. The aqueducts which cross the Campagna and the enormous buildings built in the days of the empire, were almost entirely made of brick, though facings and finishings of which they have now generally been robbed, were of sculptured marble. The Roman bricks were very thin and hard burned, but their strength and durability has been due quite as much to the far famed excellence of the Roman mortar.

Stone masonry may be considered the highest development of the art. It is at once permanent and beautiful and while in many respects no better than brickwork, it is susceptible of a finished elegance which no other material allows. Furthermore, the most

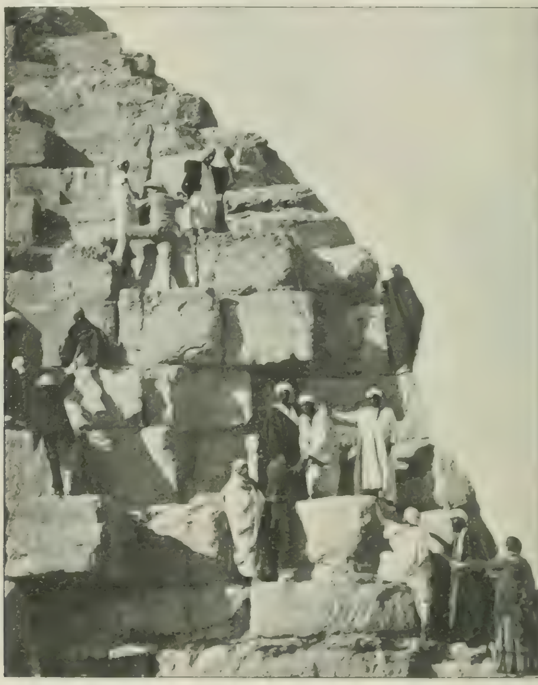

Fig. 500. Masonry of the Great Pyramids.

durable stones have a much less absorbent capacity than the best brick, and in places where masonry is exposed to moisture and to frost, as in the piers of bridges across our northern rivers, stone masonry is the best. There are a great variety of stones, but those in common use for masonry may be divided into four general classes: Granite, which is the hardest to work, the most durable against the elements and the least able to resist fire; basalt, which is generally found in inconvenient forms but which, when it can be quarried into suitable shapes, is excellent; limestones, of which there is an immense variety, from the best marbles, almost as durable as granite, to the common flinty limestones which go to pieces after the frosts of a few winters; sandstones, whose variety is almost as great as that of the limestones. The two first are azoic rocks; the two latter are of sedimentary origin. The first requirement of good masonry stone is that it should be durable; the second, that it should be capable of being

worked into convenient shape. It is possible to build good stone masonry in which mortar plays but little part.

Stone masonry may be classified in two different ways: By the shape in which the stone is used, and by the manner in which it is laid together. Masonry is divided into rubble and ashlar, while there may be combinations of the two, much good masonry having an ashlar face with rubble backing; in rubble masonry the stones are not cut; though they may be roughly blocked into shape, they are laid up in an irregular manner, with joints of varying thickness; in ashlar masonry the beds and joints are cut to vertical and horizontal planes, or more properly to planes parallel and at right angles to the line of pressure. The second division is into dry masonry and masonry laid in mortar; in the former the stones are placed directly upon each other, the bearing being taken at the points in which they come in contact; which even in the best cut stone work is not a continuous surface; in the latter the stones are bedded in mortar and the joints are filled with mortar so that, if the work is well done, the weight is distributed uniformly over the whole bed of each stone and the mortar excludes air and water from the interior of the work.

Fig. 501. "Piscina Mirabilis," Fresh Water Reservoir, Pozzuoli, near Naples, Italy.

Fig. 502. Egyptian Masonry at Luxor.

Concrete is really an artificial stone; it is composed of broken stone or gravel enveloped in a matrix of mortar which surrounds every stone, filling all the voids, in the same way in which the cementing material of the mortar surrounds the particles of sand and fills the voids between them. A good concrete should be absolutely solid, there should be enough cement in the mortar to fill all the voids between the grains of sand and there should be enough mortar in the mass to fill all the voids between the stones; the mass should be so thoroughly mixed that this distribution actually takes place, a result which is seldom accomplished in quick, hurried work. Where stone cannot be had it may be omitted and some of the best concrete ever made is formed entirely of cement and sand. While concrete is perhaps the most modern form of masonry, it is by no means new; while the Romans generally used brick for the unseen portions of their construction in many cases they used concrete; in Eastern buildings much of the interior work is of rubble masonry, containing so large a proportion of mortar that it is really concrete. Concrete is in very general use in Europe; its use is extending rapidly in America. Prejudices have been raised against it, through inferior work done in this country when it was first introduced, but it is within the limit of possibilities that an artificial stone can be made in this way, which will be as good and as durable as the natural stones which are commonly used; when this is accomplished the advantages of a truly monolithic construction will make concrete the best building material and, except for the facing of monumental works, where nothing can take the place of the finest stones from nature's laboratory, it may be universally used.

An engineer in designing a structure uses a factor of safety, which is the quotient obtained by dividing the breaking strain by the worklng strain. One of the rules which he follows in construction is to expose no material to a tensile strain when that material is not capable of some elongation without fracture, and the less such possible elongation the greater the factor of safety must be. Applying this rule, single stones are capable of a slight elongation under strain and may, therefore, be called on for some tensile resistance but only with an excessively large factor of safety. The same may be said of monolithic concrete though its general nature is such that the factor of safety should be still larger and the tensile strain permitted very small. Composite masonry, whether of stone or brick, cannot be depended upon for any such elongation, but as soon as a tensile strain occurs some of the joints are likely to open. A masonry structure should be so designed that no tension exists in any portion of it, the only exception being in single stones like lintels over openings or the covering stones of a culvert, and these act only as beams. Furthermore, it is not enough to eliminate all external tensile strains but an external compression improperly applied may produce internal tension. Long compression members of timber or metal when tested to destruction invariably break through tension. If in any body the resultant of the compressive strains in any direction falls exactly in the center of the cross section normal to that direction, the compression on that cross section will be uniform throughout. If, however, this resultant moves from such center the unit strain increases on the side

Fig. 503. Cairo (Illinois) Bridge.

Fig. 504. Memphis Bridge Piers.

toward which that resultant moves and decreases on the side from which it moves, until, when the distance of the resultant from one face is twice that from the other, the pressure on the extreme edge nearest the resultant has been doubled and that at the more distant edge has been reduced to nothing. If the resultant moves still farther the further reduction of pressure on the more distant edge gives negative results, tension appears in the masonry and fracture occurs, not where the pressure is greatest but where it is less than nothing. While this fracture may not throw down the structure, it will cause cracks and thereby destroy the monolithic character of the work.

Though tension should never be permitted in masonry it is still possible for changes of shape to occur of the same nature which take place when a beam deflects under a load. In a beam this deflection is caused by compression in the upper portion of the beam which shortens the fiber and tension in the lower portion which lengthens the fibers. Similar results, so far as distortion are concerned, may, however, be obtained by varying compression, and this is what takes place in a piece of masonry. In a long masonry column, for instance, a force applied at the center of the column would simply compress that column, shortening it in proportion to its length and the strain. If, however, this pressure instead of being applied at the center were applied at the edge of the middle third a compression would take place on one side of the column equal to double what under the former conditions took place throughout the whole, while there would be no

compression on the other side; the column might, therefore, be bent perceptibly out of shape without the existence of any tension in the masonry. Masonry has a modulus of elasticity, or as some physicists would prefer to call it, a coefficient of compression. Its elasticity must be recognized and masonry is susceptible of an amount, though a small one, of deformation and this deformation is not infrequently observed in practice. The piers of many bridges bend back and forth and this without injury to the masonry.

The ideal masonry would be absolutely monolithic; this result, however, is never obtained except in concrete. In all other kinds two conditions are relied upon to produce this result in some measure. The first of these is the friction of the stones upon each other; as friction is directly proportionate to pressure the best re-

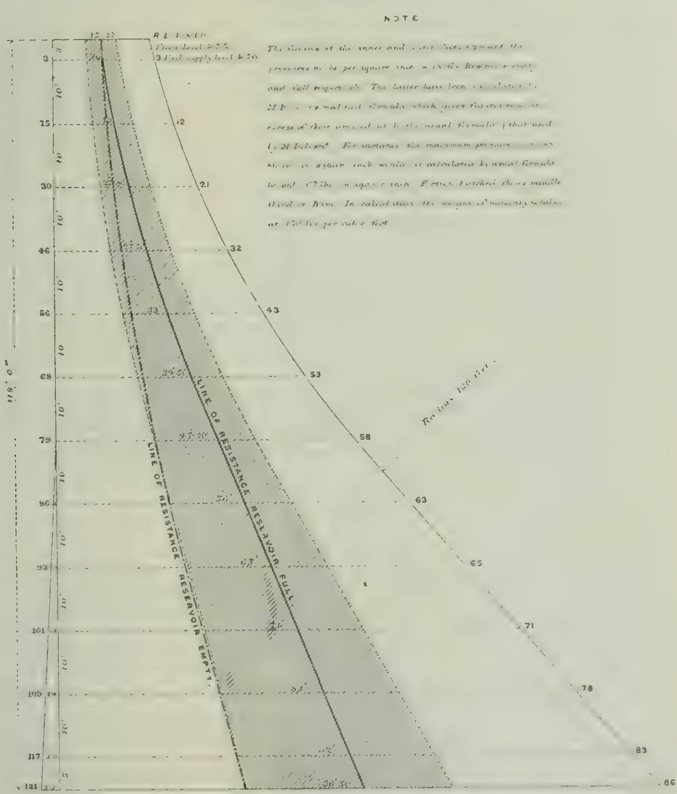

Fig. 505. Tansa (India) Dam.

sults are obtained when the maximum pressure is combined with the least tendency to move on the lines of friction; this condition obtains on planes which are at right angles to the line of

pressure, so that the pressure on the plane is a maximum and has no component in the only direction in which the stones can slide. Furthermore, this friction should be utilized to tie the successive stones together as much as possible; the stones in one course should tie together those in the course below, that is the

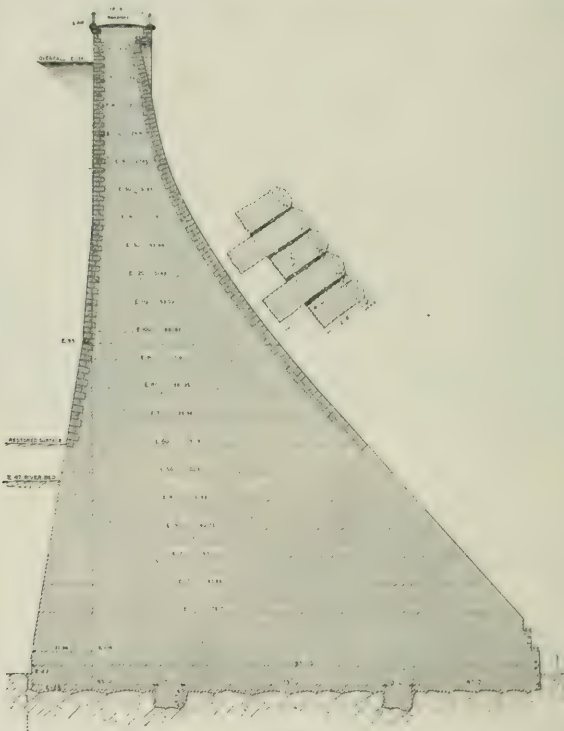

Fig. 506. Cornell Dam.

stones instead of being superimposed on other stones should be placed over the joints between the stones below, so that stones cannot be pulled apart without overcoming this friction. This breaking of joints is a fundamental principle of good masonry. The most perfect form of a pier intended to resist weight would be one formed of successive courses, each consisting of a single stone, the pressure being taken at the successive joints on planes at right angles to the line of pressure. In very small structures this is sometimes done with excellent results; in larger works the nearest possible approach to this is obtained by using successive courses separated by parallel planes, the stones of one course breaking joints with those of the course below and binding those stones together by this frictional resistance. The best quality of

Fig. 507. Prize Design Connecticut Avenue Viaduct, District of Columbia.

ashlar masonry fulfills this condition better than anything else; well bonded brick work does it also.

The other condition which tends to produce monolithic work is the use of mortar, with which all interstices should be filled and which has the double effect of reducing the pressure by distributing it over surfaces instead of taking it on points and of very greatly increasing the coefficient of friction by its adhesion to the stones. The better the mortar the better these results. A perfect mortar would be as strong as the stone and would adhere to the stone as firmly as the particles of stone adhere to each other (a degree of excellence which we shall probably never attain). With such a mortar the work would become absolutely monolithic and it would no longer be necessary to use beds at right angles to the line of pressure or to break joints, as both beds and joints would disappear in the absolute monolith which would result.

With the mortars which we now use it may be said that the closer the work, the truer the fitting and the less amount of mortar required to fill all voids the better the work will be. With ordinary workmanship, however, there is danger of carrying this too far. It is better to have a thick bed of mortar which will absolutely fill the space between two courses of stone so that every bed is supported throughout by the mortar than to have a thin joint in which this is not done. It is much harder to fill thin joints than thick ones, and in ordinary practice it is not wise to make the joints too thin. I have usually put a clause into specifications for first-class masonry providing that thin horizontal mortar joints will not be insisted on, but that every stone shall be set in a full bed of mortar and settled to a proper bearing.

There is a common idea that the same degree of excellence, or of inferiority, should be permitted in all features of a piece of work. In other words, that in second class masonry in which little pains are taken in fitting the beds and joints, a poorer mortar may be allowed than would be required in first-class ashlar work. This is entirely wrong, the closer the work, the nicer the fitting and the more perfect the shape of the stones, the greater is the work done by friction and bonding and the less is the duty which the mortar performs. If poor mortar is to be permitted at all it should be allowed only with the very best stone work. The inferior classes of masonry, like rubble work, if they have any considerable duty to perform are only safe when laid up in very best quality of mortar. This is illustrated by the work of different nations. The closest stone cutters the world has ever seen were the ancient Egyptians; the great pyramid is a mass of ashlar masonry, though the face stone was stolen by Mohammedan invaders to build the mosques and seraglios of the city of Cairo; but in one place, where the sands of the desert have been uncovered from a small remnant of facing near the base of the pyramid, I found a joint on the top bed of a stone which did not exist on

the face; a careful examination showed that this could not be a real joint, but must have been simply the mark of the tool which was used in trimming the end of the stone which formerly stood in the course above, and yet the real joint was so close that it could scarcely be distinguished from this tool mark. The pyramids were laid up in mortar, but the amount used was almost infinitesimal and was simply an inferior lime paste; the excellence of the stone work rendered the quality of the mortar unimportant. The masonry of India is very different; it is made largely of small stones with a facing of fine work, but the mortar, the work of the patient, mild Hindoo, is very good; the masonry is of excellent character and very strong; the smallness and poor fitting of the stones are made up for by the excellence of the mortar.

As an extreme instance of imperfect specifications I may mention a case which recently came to my attention: a wall of rubble masonry, with poorly bonded stones and irregular beds, laid in inferior mortar, was run up quickly to a height of nearly fifty feet, when suddenly the exact result which was to be expected occurred: the mortar in the lower courses yielded, the stones moved on each other and the entire wall collapsed into a heap of loose stones and looser mortar. Poor as the mortar was, if the wall had been built of cut stone, well bonded, it would have compressed a little and have stood. Poor as the stone was and weak as the bonding was, it would have stood if the mortar had been good enough to bear a moderate pressure and to adhere to the stone; the mortar neither adhered to the stone nor was able to carry the weight of the wall; fortunately destruction came before the building was completed.

Mortar plays a very important part in all except dry masonry and especially in concrete and the inferior forms of stone work. The simplest form of mortar is a well worked clay, such as adobes are laid up in, and with which the brick chimneys of many of the older farmhouses in our country were built; but the use of clay has practically gone by except in furnaces and ovens where the heat resisting capacity of fire clay is more important than the superior strength of a good mortar.

Mortars are generally formed of lime or cement and sand. A lime mortar does not set but hardens slowly. A cement mortar sets quickly and then continues to harden. The hardening of the lime mortar is a slow chemical action between the lime and other elements; the best results are obtained by mixing the mortar some weeks before it is used and not subjecting it to any great strain till a considerable time after it is laid. The action of cement is different; the cement itself contains all the elements necessary to the setting and hardening; a briquette of pure cement will set harder and be stronger than a briquette containing even a small portion of sand. The function of sand in a cement mortar is simply that of a dilutant and is precisely similar to that of broken

stone or coarse gravel in concrete. In a cement mortar there should be enough cement to fill all voids between the grains of sand, which implies a coating of the entire surface of every grain, and enough more than this to provide for the contingency of imperfect mixing. The more perfect the mixture the less the amount of cement that will be required, and the finer the cement is ground the less cement it will take to coat every particle of sand.

In both lime mortar and cement mortar the best results are due to work; the more complete the incorporation of the ingredients the better the mortar will be. In lime mortar, which hardens slowly, time need not be considered and this incorporation can be done slowly. In cement mortar where a set takes place early it is important that too much time should not be spent in mixing. In the alluvial deposits of the Ganges is found a kind of limestone of irregular shape known as kunker; the Hindoos make a mortar of kunker lime and brick dust which becomes as hard as Portland cement; the piers of the great bridge across the Ganges at Benares are laid in this; its excellence is due to work. A similar excellence is found in all their mortars; when the lime has been slacked they grind it in a hand mill, then they grind the sand in a similar mill and then they grind the lime and sand together, all of this work being done by women; the mixture is then wet and ground in a mortar mill with bullocks and when it is used it is pounded for hours. They will take this mortar, plaster a wall, pound it and rub it down and the final result of their patient work is a plastered wall, with a polished surface as smooth as that of porcelain, which will stand the weather of their frostless climate for more than a century. The secret of good mortar is work; in India, where labor is hardly worth five cents a day, this can be done by hand; in this country we cannot afford it; it is cheaper to use the most costly cements, but even cement mortars are better if thoroughly worked, and I hope to see the time when machine mortar mixers are as common on masonry walls as power riveters are now in bridge shops

As the capacity of masonry is limited, so are also its uses. Its use must conform to conditions of stability without tension and this necessarily limits its applications. Masonry is an art by itself; the laws of its construction are complete in themselves and the best masonry is found in those countries where other structural methods do not generally prevail.

The Japanese, who have preserved and cared for their forests, are exquisite carpenters and nearly all their buildings are of wood; their temples are the most elaborate specimens of timber construction that can be found. On the other hand their country is subject to frequent earthquakes and masonry has been but little used. Their constant use of timber has led to building structures

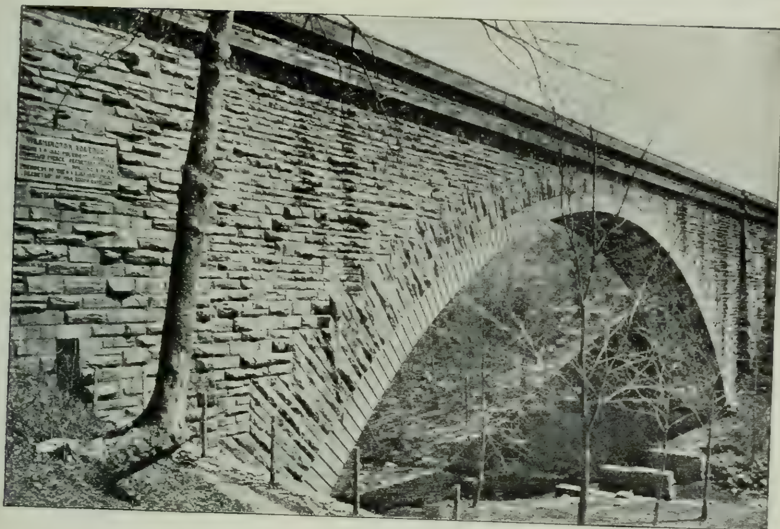

Fig. 508. The Cabin John Bridge, Washington, D. C., Aqueduct, longest masonry arch in the world.

which are absolutely absurd; they have applied the principles of timber construction to stone work; there are bridges in Japan which are supported by bents composed of stone posts tied together by horizontal stones which pass completely through the posts; at the entrances to their temples are stone gateways, made of framed posts and caps, which look like wood; all this is bad. One of the strangest designs that I have ever seen was that of a monument to be erected in the capital of one of our larger states; externally it appeared to be a decorated piece of solid masonry, but internally it was a stone frame based on lines properly adapted to timber construction. It had been selected from several designs by a board of architects but fortunately was submitted to an engineer before it was built.

The first and simplest use of masonry is as a support to carry weight, as in a column or a bridge pier. For this purpose it is an absolutely appropriate material and the satisfactory results which have been obtained are illustrated by the heavy columns of the ancient Egyptians, by the exquisite work of the Greeks, and the slender shafts which preserve to this day the beauty which we imitate but do not equal. For bridge piers masonry is by far the most suitable and best material. An ordinary truss bridge is so designed that practically no horizontal strain is imparted to the masonry which simply carries the weight imposed upon it. If made of good stone, masonry is better able to resist the action of water and air combined with changes of temperature, than anything else. A bridge pier should be built of ashlar masonry with horizontal beds and well bonded stones. Rubble backing may be

used if thoroughly filled with first-class mortar, but a backing of stones, with horizontal beds, of the same thickness as the face stones is better. The following clauses, which illustrate the class of work which I have preferred to use, are taken from the specifications for the bridge across the Missouri River at Bellefontaine Bluffs:

Each bed of every stone shall measure at least twenty-six inches in each direction, except that where the thickness of the course is less than twenty-four inches the bed need not exceed one and one-half times the thickness of the stone.

The bottom bed shall always be the full size of the stone and no stone shall have an overhanging top bed.

Stretchers shall not be less than four feet nor more than seven feet long, and stretchers of the same width shall not be placed together vertically, but this shall not apply to the ends of stretchers where headers come centrally between stretchers.

Headers shall be at least five feet long and shall be at least three-quarters their full width for the whole length. There shall be at least three headers on each side of every course between the shoulders.

Joints shall be cut vertical and at right angles to the face of the stone unless otherwise shown on special plans. The cutting for at least twelve inches back from the face shall be the same as that required for the beds.

Joints shall be broken at least fifteen inches on the face.

The backing shall be composed of stones of the same thickness as the face stones, with beds cut in the same manner as required for the face stones and with no overhanging top beds. The spaces between the large stones shall not occupy more than one-fifth of the entire area of the pier inside of the face stones, and these spaces shall be filled with good rubble masonry carefully laid up in full mortar beds and well rammed.

A bridge pier has two functions; it must carry weight and it must pass water with the least disturbance to that water. This calls for the same kind of lines that are needed in a boat; corners are to be avoided and the best results are obtained by piers which are pointed at both ends but have no other angles. The form of pier which I have found to give best results has straight parallel sides terminating in circular curves, to which the sides are tangent. A considerable variation can be allowed in the radius of the end curves but a radius equal to about three-fourths the thickness of the pier gives very good results. The down-stream end may be made semicircular without seriously injuring the form, though it creates more disturbance in the passage of water. Sometimes a semicircle may be used at the upstream end, but in rivers carrying any considerable amount of drift this is liable to cause trouble. A common form of pier is hexagonal, with parallel sides, a right angle at each end and an angle of 135 degrees at each of the four shoulders; this, however, is not a good shape as the angle at the shoulder is sharp enough to make a great disturbance in the passage of water. Nearly twenty years ago I adopted a plan of bridge pier which I have never thought fit to change. The cross section between high and low water is of the kind which I have described; above high water the ends are made semicircular; the pier is finished with projecting coping and a belting course under it on top, and the offsets near high

Fig. 509. Small Gateway in Western Fortification Wall, Assos.

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water are covered by small copings. The pier is very plain but is perfectly adapted to its purpose and always looks well. It is perfectly symmetrical so that the pressure on the foundation is as nearly as possible uniform. In low bridges where the piers finish but little above high water no change in shape is made. The long raking ice breakers which were formerly popular are rarely needed with heavy piers of good masonry; when used they necessarily throw the center of pressure outside of the center of masonry and make unequal weights on the foundation.

Another proper use of masonry is that of retaining walls, including the abutments of bridges. The duty of a retaining wall is double; it has to carry its own weight as well as any weight that may be put on it (like the superstructure of a bridge when it is an abutment), and it has also to resist the horizontal thrust of a mass of earth behind it, the resultant of the horizontal and vertical strains being a curve more or less inclined. To produce the best results the masonry should be laid up in inclined courses, the joints being everywhere normal to this resultant curve; in some cases this has been done. The wall must be so proportioned that the resultant curve shall never pass outside of the middle third, and this means that the weight of the masonry, which acts downward, must be greatly in excess of the thrust of the earthwork which acts horizontally. The principal duty, therefore, of a retaining wall is to provide weight and a large amount of cheap masonry may be better than a smaller amount of first-class masonry. Good rubble masonry and concrete are excellent materials for retaining walls. One of the most satisfactory retaining walls I have known was built of concrete, made with Louisville cement and faced with a single thickness of brick, the brick being bonded into the concrete by making every other brick a header in every second course. There is no class of structure, the determination of the strains in which is more uncertain than a retaining wall. The principal difficulty lies in the uncertainty of the thrust of an earth embankment which varies with the amount of saturation, by the method in which it is made and by irregularities of both time and place. It is perhaps as safe to follow arbitrary rules as to make close calculations; a common rule being to make the thickness of a retaining wall never less than 40 per cent of its height above such thickness; with some favored soils this may be reduced to 30 per cent, but where subject to vibrations or other disturbances it should be increased to 50 per cent. It must also be remembered that nearly all foundations are compressible and that the pressure on the foundation of a retaining wall may increase from nothing at the back to twice the average at the face, which means that a retaining wall on a yielding foundation will move forward to an extent which can seldom be estimated, but which must generally be provided for.

A form of retaining wall which is free from these latter defects is the masonry dam, which instead of a pressure of earth resists a

Fig. 510, Rahway Avenue Arch, Penn. R. R., Elizabeth, N. Y.

pressure of water. This is a pressure which can be calculated absolutely and the dam can be proportioned to take care of it exactly. The design of a dam is complicated, not by uncertain data, but by the fact that the level of the water behind it may vary from nothing to the maximum height permitted by the spillway, and paradoxical though it may seem, a dam which is perfectly safe to sustain a head of water 100 feet high may have tension cracks open on the lower side when the head is only half as great. In dams, masonry is needed principally for weight, and as with the difference of level of water the resultant curves of strain are constantly changing a dam cannot be so designed that the beds of the stones shall at all times be normal to the resultant curve of strains. There is little advantage in using ashlar masonry in a dam, and the best dams are built of rubble or of concrete; but it is very important to use thoroughly good mortar and to make sure that all the voids are filled, as openings mean leakage. One of the great dams of late years is the Tansa built for the Bombay Waterworks; a dam 118 feet high, built of rubble laid in kunker lime mortar made with the patient excellence already described.

The problems of the builder early called for the covering of openings between pillars and over doorways and then for the complete covering of rooms. It was solved by the use of lintels and architraves, single stones being used as beams. Where rooms had to be covered, if they were not too large the same method was followed; this was common in all the ancient Egyptian work.

The spanning of openings with masonry is not, however, limited to small dimensions and the form of construction most available for large spans is the arch. In columns and piers the

only strains to be resisted are those of gravity acting in vertical lines. In retaining walls and dams these strains are combined with horizontal pressure producing inclined resultants. In arches, weights which originally act only in vertical lines, being carried outside of the lines of support, necessarily involve inclined resultants, which introduce horizontal strains. Without going into the theory of catenaries it may be briefly stated, that a loose cord fastened securely at each end has some form of stability for every loading which can be put on it, the cord, however, always being in tension; that if this curve, which is stable for a particular loading and no other, is inverted, it is stable for the same loading but is in compression and not in tension; but though the cord in tension by changing its shape for every change in loading preserves its stability, the inverted catenary in compression would go to pieces with a very slight change of load. Furthermore, the shape of the catenary will adapt itself to the amount of slack left in the cord; the intensity of the strain is roughly proportionate to the amount of the deflection below a line connecting the two points of end attachment, and the same is true of the inverted catenary in compression. A masonry arch should act only in compression and the strains in it are those existing in the inverted catenary. For every loading there is some form of arch that will correspond exactly to the curve of strain. For every form of arch there is some loading which will correspond exactly to its shape. So long as the curve of strain does not pass outside of the middle third of the arch, the arch is perfectly stable and no tension occurs anywhere in the masonry. The masonry of an arch should be so laid that the joints are everywhere normal to the curve of strain, this being the direction in which the pressure acts. The perfect form of an arch which is to carry a variable load of which a portion is permanent or static and a portion moving, like a railroad train crossing a bridge, is one in which the curve of permanent strain follows the center line of the masonry and the curve, as modified by the different positions of the moving load, never passes outside the middle third.

An arch is entirely without stability until it is complete; it is self-sustaining only when the pressures are carried across from one side to the other, these pressures being horizontal at the crown. An arch, therefore, must be supported by something else than itself during construction, and this is usually accomplished by building it on a timber form known as a center, the center carrying the weight of the arch until the last voussoir, known as the keystone, is put in; when it is placed the centers are struck and the arch settles slightly, as the joints for the first time take the pressure due to the weight. There is always a horizontal pressure at the keystone and this must always be balanced by an equal horizontal thrust at the spring of the arch. Where several arches are built together the thrusts of successive arches will balance each other and they may be supported on thin piers proportioned

Fig. 511. Oakly Arch, Skew 42 Deg. 30 Min.

only to sustain the weight. But in the case of a single arch or of the end arches in a long arcade, the piers must be made heavy enough to resist this thrust. In other words, they must be of such dimensions that the combination of this horizontal thrust, with the vertical action of weight, will never fall outside the middle third.

Arches are built of various shapes; one of the commonest and most beautiful forms is the full centered arch, that is, the arch is itself a half circle. This is the form usually adopted for monumental work; it is, however, a form which requires very careful treatment; if the filling above the arch is built up solid, the weight distributed over the arch does not correspond to the form of the arch and rupture is likely to occur in the haunches; this is obviated by using a hollow filling over the haunches, which may be accomplished either by cellular construction, or, better, by building up the spandrels with cross walls supporting small arches.

A favorite form, and in many respects the best, is the segmental arch, that is, an arch which is a segment of a circle, the preferred dimension being one in which the rise is one-quarter the span. With these proportions there is less difficulty in conforming the load exactly to the curve of the arch. Another form is the elliptic arch, which is usually not a true ellipse but formed of either three or five circular arcs. As commonly built the elliptic arch is really a segmental arch with the angle at the skewback filled out. To these may be added the pointed arch, which is characteristic of Gothic architecture and an endless variety of parabolic, hyperparabolic and other special shapes.

The essential characteristic of an arch is that it should act only in compression resisting the strains, which follow the curve produced by weights, by compression only, this implying a thrust at each end. This thrust can be taken by tension rods of metal, but in monumental structures should be resisted, like the thrust of the earth against a retaining wall, by the weight of the masonry. These features of construction are absolutely necessary; without them, whatever the shape, no arch exists. People who are influenced by the vagaries of amateur art talk of finding the Gothic arch in the meeting boughs of overhanging trees or find the circular arch in the bent sapling with which a savage constructs his rude hut; both ideas are absurd. The first arch was built when two inclined stones were first balanced against each other; such an arch may still be seen at the entrance to the passage leading into the great Pyramid. The next step was to use three stones instead of two and from this progress was rapid to the perfect arch. To understand an arch, it is absolutely necessary to remember what it does and the duties of overhanging trees or of bent saplings are entirely unlike the duties of an arch.

Besides the simple arch which we may say is in one plane only, the principles may be adapted to a great variety of constructions. An arch may be used to connect two supports or piers which are not at right angles to the line of support, this makes a skew arch. This form of arch is perfectly correct and stable provided the voussoir joints are made at right angles to the curves of strains, which curves are in planes parallel to the center line of the arch and not at right angles to the direction of the piers. A simple way of meeting this result is to build a series of narrow square arches, the successive arches making offsets corresponding to the tangent of the angle of the skew. This simplifies stone cutting but it is not necessary and the laying out of the correct voussoir lines for a skew arch is an excellent exercise in masonry designing.

If two arches of considerable width intersect each other they form a groin, this combination being known as a groined arch, the simplest form being that in which two arches of the same dimensions cross at right angles, but the same principle, may be applied with arches at various angles and of various dimensions. Gothic architecture probably had its origin in the groining of the narrow arches of the aisles with the larger arch of the nave, the pointed arch accommodating itself to those conditions. Groined arches are adapted to a great variety of uses and might be applied to many structures where other methods are commonly used. An excellent form of flooring for fire-proof buildings is made by a series of flat groined arches resting on columns spaced at equal distances in both directions, the thrusts of the arches balancing each other and the whole floor requiring no metal work except horizontal girders around the edges to take the thrust of the outside arches, and these horizontal girders may be so buried in the floors as to be very light.

There is a form of construction which looks like an arch but is not one. The most beautiful architecture since the days of the Greeks is that which was carried by the Mohammedan conquerors as far west as Spain and as far east as India; the architecture with

Fig. 512. Arch of Septimius Severus.

swelling domes, with arches apparently more than full centered, finished in fantastic and graceful shapes. In reality there are neither arches nor domes in this architecture; everything is laid up in horizontal courses, the stones being corbled out over each other. It is a construction entirely without horizontal thrusts which permits of the slender columns and graceful forms which characterize this beautiful work.

The arch should be used cautiously in monumental works. The fundamental idea of a monument is indefinite duration; it is built to commemorate some event; it is to be the eternal record of that which has itself passed; it should also be a pleasant thing to contemplate. The idea of indefinite duration is agreeable only when coupled with an idea of rest. The nirvana of the Buddhist is the most soothing of ideas; the labors of Sisyphus were the most excruciating of tortures. Structurally the idea of compression is one of rest, as when the whole weight of the body is supported; the idea of tension, which calls for muscular resistance, is an idea of strain. It is said that the ancient Egyptians never used the arch because it did not comport with the feeling of rest which characterized all Egyptian architecture. This is hardly correct; even an Egyptian pyramid does not typify rest more than a stone arch thrown across a mountain gorge. The feeling of strain does not come from the arch itself, but from the apparent effort of the abutments to resist its thrust; and in a monument this appearance can be removed by making the abutments of such dimensions as not only to resist the strain, not only to bring the resultants within

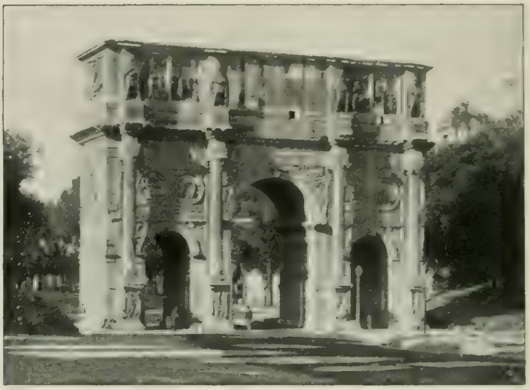


Fig. 513. Arch of Constantine.

the middle third, but to give such a superfluity of material that the idea of effort never occurs to the observer. This rule should not apply to the various buildings and other works which serve pre-eminently a utilitarian purpose, but it does apply to all monumental work. The Romans built triumphal arches, and, though the special ceremonies which they commemorate have passed away, they are still built. The Roman arches were not all handsome. In the arches of Constantine and Septimius Severus the arch occupies only about one-quarter of the length; each abutment is one-half thicker than the span of the arch; these arches are true restful monuments. In the arch of Titus the proportions are different, the thickness of each abutment being about three-quarters the span of the arch. The great arch in the Place d' Etoile in Paris is one of the finest ever built. The arch in Washington Square, in which the thickness of the abutment is only one-half the span, is one of the worst.

Washington Arch, New York.

Fig. 514. As it Should be. Fig. 515. As it is.

The arch, whether in simple or complicated form, is not the only method of spanning large openings with masonry. A method is found in India by which openings are covered by stones much smaller than would be required to reach completely across the opening, the stones being laid across the corners of a square leaving open another square just half the size of the first, the system being repeated until a square is obtained small enough to be covered by stones reaching completely across. Such methods of using stone, however, while interesting features of masonry construction, are very simple, and as they are only

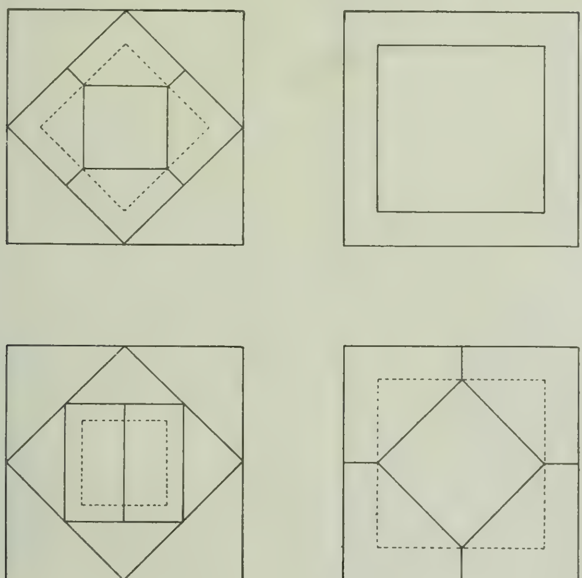


Fig. 516. India Roof Covering.

adapted to small dimensions, they call for little consideration from engineers. Another method is the dome. The dome seems like a modification of the arch, being, as it were, the solid produced by the rotation of an arch. The dome, however, is not an arch but a construction of very different character, the strength of which is determined by different conditions. An arch is self sustaining only when it is complete; it must be supported in some other way until the keystone is placed. A dome has no keystone; the central portion may be entirely omitted without imparing its stability; it may be built up without false work; each successive ring is completely self-sustaining as soon as it is built; it is only necessary to support the separate stones or bricks of each separate ring until that ring is completed and there are various simple devices by which this can

be done. This element of stability in a dome is understood when it is remembered that neither an arch nor a dome can fall unless it falls forward from its support; in an uncompleted arch there is nothing to prevent this; an uncompleted dome cannot fall forward without diminishing its diameter, and the diameter of a circle of masonry cannot be reduced without crushing the material of which it is made. At its base the dome exerts a thrust outward in every direction but the thrust inward towards the center is resisted by a horizontal circular arch.

But though the dome requires no keystone, its weight must be carried downward from the axis towards the circumference where it is supported, and the weights of a dome carried down in this way produce, like those of an arch, a resultant curve. This curve represents only the strains in plains radial to the axis and does not include any of the circumferential strains by which the dome is always self-sustaining. This resultant curve is dependent on two forces, the vertical action of weight, and the horizontal strains which are resisted by the circular form of the dome. The weights are known quantities; the resultant curve may be assumed to be in the middle of the masonry, in other words, to conform to the curve of the dome; the problem is the determination of the horizontal strains with the vertical weights and the resultant curve given; this can be done graphically or by analysis. When these horizontal strains represent forces acting towards the center, the dome is stable; if, however, they represent forces acting outwards, the dome is unstable and will burst unless held by a metallic band. Two classes of strains will always exist; those following the vertical curve of the dome; circumferential strains which are everywhere equal to the radial horizontal strain multiplied by the horizontal radius of the dome in the same plane.

As in the case of the arch, a form of dome may be found which corresponds to every condition of symmetrical loading and a form of loading may be found which corresponds to every form of symmetrical dome. The forms and loadings, however, vary greatly and many forms of stable domes are excluded by the inconvenient shapes which they involve Furthermore, any dome may be made stable by strapping it with iron at the place where it tends to rise, a method which has been often adopted in domes which are supposed to be entirely of masonry.

A dome of uniform thickness is always stable when the height does not exceed one-quarter of the span. but such a dome would at once become unstable if loaded with a heavy central lantern. It is a significant fact that low domes of this proportion are almost always pleasing to the eye. The dome exerts an outward thrust at the base, and this thrust can be resisted in two ways, either by a weight of masonry in the same manner that the thrust of an arch is resisted or by a hoop of iron which straps the whole together. The former is the true restful method of masonry construction, the latter is a mechanical device perfectly proper in utili-

tarian construction, but wrong in monumental work. And this leads to a suggestion of a class of domes which can be used for many purposes and be very effective. If a dome be built of concrete with a series of parallel steel rings imbedded in it, it will be able to resist both tension and compression horizontally throughout, and can neither rise nor fall. Such a dome could be built very light, and could be made of almost any symmetrical shape. Various details of construction could be introduced which would admit light through such a dome and it would form an admirable covering in many large rooms.

Domes have generally been built of circular horizontal section. Half domes, however, are equally stable if provision is made for taking the horizontal thrusts on the terminal diameters. This

Fig. 517. Reproduction of the Parthenon at the Tennessee Centennial.

can be done by turning an arch of the same curve between the two half domes or by other more complicated methods. A room of the form of a rectangle with semicircular ends can be covered by two half domes over the semicircles and an arch over the rectangle, the arrangement being perfectly stable, provided the walls are heavy enough to resist the thrust of both domes and arch, the latter being the more intense.

A dome may be made of elliptical section which would be perfectly stable and entirely satisfactory, but it would require varieties of loading, which would vary the horizontal thrusts to conform to the eccentric shape. It is an interesting problem to work out.

Fig. 518. Taj Mahal at Agra, India.

Neither the dome nor the arch is found in the oldest masonry. The arch undoubtedly preceded the dome. The true study of architecture is the mastery of the principles involved in the arch and the dome. The home of the dome was on the Mediterranean; it was used by the Romans; it was carried to its highest perfection in the Eastern empire; it was developed in the days of the Renaissance, and it was brought by the Spanish conquerors to America; it is perhaps the highest development of masonry construction.

The really fine domes are comparatively few; many of those which are best known are humbugs, more false than the false arches of the East, in that they are made of wood and pretend to be entirely unlike what they are. The upper portions of the famous domes of St. Mark's at Venice are of wood; the dome of the Invalides in Paris is of wood; the outer dome of St. Paul's in London is of wood, the lantern being carried on a brick cone inside. The dome of St. Peter's at Rome is of stone, but it proved unstable and had to be strapped with iron. These modern humbugs are poor things compared with earlier works. The dome of the Pantheon in Rome is perfect, with its central opening to the sky and bound by the weight of the massive circular brick walls. The development of the dome reached its highest perfection in the sixth century, when in the capital of the Eastern empire was

erected the great church. which, after serving for nine centuries, as a Christian church, and for half that time as a monotheistic mosque, still stands, the finest specimen of ecclesiastical architecture ever built; its impersonal name being significant of the skill of its design, Sancta Sophia, the church of Divine Wisdom.

I have spoken of the general ideas and principles which should govern the use of masonry. It is the one material which is available for really permanent work. It should be massive and it must be well done. It is the most expensive form of good construction; it belongs to the class of works which are commonly associated with architecture rather than with engineering. It is the business of the engineer to build tools to produce practical results; he will, therefore, often select some lighter and cheaper form of construction which will give more immediate returns. The one material adapted to monumental work is masonry; honest substantial masonry; not a veneering of cut stone which covers a skeleton and gives a massive external appearance, which is nothing but a cloak concealing iron bands and beams within. The use of varieties of material, as an interior of brick and a facing of stone, is perfectly legitimate, provided the interior be good solid masonry throughout; but an external shell which is simply a false covering, however convenient it may be in a tool, does not belong to a monument. The great works of antiquity were built by men who knew what they were doing, though their knowledge was gained by experience and not by scientific education. With our present knowledge of materials and of the theoretical laws of strains, we should be able to do better work than has ever been done before. Metaphysicians speak of the doctrine of unconscious mental modifications. It has a counterpart in something of the nature of unconscious education, by which the eye and mind, even of the untrained man, never permanently recognizes as good anything which is not built on correct lines of construction. A piece of monumental masonry which does not appear to be in a state of rest will sooner or later cry out in its trial and then everybody will see what is wrong. The construction of good masonry and its development into the noble forms of its more complicated possibilities must be based on a thorough knowledge of the duties which are imposed upon it, and on this only; decoration and ornamentation must follow, not precede. The construction of such masonry may not be the work of an engineer, but it must be the work of a man educated like an engineer, and who knows how to direct the great powers of nature, if not to the uses and conveniences, at least to the monumental graces of man.

LV.

CONSTRUCTION OF RETAINING WALLS FOR THE SANITARY DISTRICT OF CHICAGO.

By JAMES W. BEARDSLEY, Mem. W. S. E.

(*Read Nov. 2, 1898.*)

The Main Channel may be divided for convenience into three natural divisions: First, the earth sections extending from the intersections of the Main Channel with the West Fork of the South Branch at Robey street to Willow Springs; second, the earth and rock sections extending from Willow Springs to the vicinity of Lemont, and third, the rock sections extending from Lemont to Lockport.

MASONRY WALLS.

Masonry retaining walls are built from the rock surface up to an elevation of +5.0, Chicago City Datum, throughout the second division, and concrete retaining walls are built up to the same elevation for the last mile and a half of the third division.

The channel is contracted at Willow Springs to a width of 160 feet at grade with vertical channeled sides or retaining walls, as the conditions may require, and the slope doubled.

The rock used in both masonry and concrete walls was taken from the adjacent excavation. It is Niagara limestone deposited

Fig. 519. Theoretical Cross-Section of Retaining Walls.

in practically horizontal layers of varying thickness, up to about four feet. The lack of suitable rock for rubble masonry at the lower section caused concrete walls to be decided upon. Ledges of the so-called "tame" rock were quarried readily into rectangular blocks and required practically no cutting, except for the face of the wall. No work was required on the bed joints, the general depth of a stratum was from one to one and one-half feet.

The first designs and contracts called for a dry wall; when a cement wall was ordered. the original design was retained without material change. Fig. 519 shows a theoretical cross section of the wall and backfilling with dimensions. In case the elevation of the original surface of the ground was above +5.0, the slope of the backfilling is one on ten until that surface is intersected. In case the elevation was below +5.0, a berm 50 feet in width is extended out level with the top of the wall. The latter case is exceptional.

Fig. 520 shows an actual cross-section view of the wall during

Fig. 520. Cross-Section of Retaining Wall.

construction, and the scabbling The courses are exceptionally thick. A four foot scale is shown against the end of the wall.

Fig. 521 shows the union between the earth sections, 210 feet wide at grade, with two on one side slope, and the rock sections 160 feet at grade, and 163 feet at top of walls, at Willow Springs.

The general specifications limited the thickness of courses to 30 inches, if greater, the additional rectangle at the back of the wall was not allowed in computing yardage. An extended series

Fig. 521. Union of the Earth and Rock Sections.

of measurements of each course of a wall, built from a quarry containing strata somewhat thicker than the average, gave an average of 15 inches for the thickness of courses. The different contractors accepted this average thickness as a fair basis for yardage. A large amount of field and office work was thereby saved.

Some of the principal items in the general specifications are quoted as follows:—

"The sides of the channel are to be walled with masonry as soon as practicable after the channel is opened, provided suitable stone can be found in the excavation on said section which will conform to the specifications as follows:—If the bottom of the channel is in earth or glacial drift the retaining walls shall be founded upon a footing made in a trench dug not less than one foot below grade, and as much deeper as may be directed by the Chief Engineer, said footing course to project 12 inches beyond the face of the wall. If the bottom of the channel is in rock the retaining walls are to be founded upon the surface of the rock.

"Before beginning the construction of the wall the surface of the rock is to be cleared of earth and foreign substances, and all

loose and soft rock is to be removed from the full width of its base, that the wall may be founded upon a clean solid stratum. If this stratum of natural rock inclines towards the Main Channel with such an inclination and such manner as, in the opinion of the Chief Engineer, to render the footing of the wall liable to slip on the same, the contractor shall excavate the top surface of the rock parallel with and beneath the proposed wall in accordance with the directions of the Chief Engineer, so as to effectively remove all liability of slipping.

"The retaining walls are to be built of stone from the section, those of the largest size and most regular rectangular shape being selected for the faces and main binding stones; the face of each wall to be laid true to line, the stones being scabbled and carefully placed in a firm position on their natural quarry beds.

"The walls are to be laid in courses or layers. In laying each course the larger stones are to be carefully placed in position, covering the face of the wall in such a manner as to break joints with the larger stones of the preceding course.

Mortar: "The mixture shall be of sand and cement in equal parts. The sand and cement shall be thoroughly incorporated with each other before water is added. All mortar shall be freshly mixed in clean boxes. No hard or partially set mortar shall be used. Water for mixing shall be clean. In laying the wall care shall be taken to secure bond by proper use of headers and stretchers, so far as the stone available for the work will admit, but the wall shall be so thoroughly slushed with cement mortar as to insure the filling of all interstices and the development of a monolithic mass so soon as the mortar shall have set. Stone used shall be sound and clean. The wall shall be pointed with the specified mortar throughout, before acceptance; all joints shall be raked out to a depth equal to three times their width, to receive pointing, except when pointing is done as the work progresses.

"Work on cement masonry walls to be begun after the period of freezing in the spring, and to be suspended before the freezing begins in the fall.

Cement: "The best American hydraulic cement is to be used, brand and quality to be subject to approval by the Chief Engineer, who shall from time to time cause such tests to be made as may seem to him proper for determining the quality of the cement which is shipped for use in the work.

"The development of tensile strength shall be 100 pounds per square inch, after having set seven days.

"The contractor shall keep on hand a supply of cement equal to the average consumption in the work during a period of ten days, and it shall be protected against rain or dampness and so stored as to make the procurement of samples for testing easy.

"All lumpy, dirty or damaged cement shall be rejected; also damaged or short weight packages.

"Face of wall to be fair, and to have good joints.

"No stone, no matter what size, is to be put in the wall without a full bed of mortar of proper quality, it being considered necessary to be absolutely certain that all spaces between the stones are filled solid with mortar.

SPECIFICATIONS FOR SAND.

General: "Sand used to be coarse, clean, sharp and free from loam and pebbles.

Special: "The coarseness of the sand shall be determined as follows:

1st. "To be free from pebbles over one-eighth (⅛) inch in largest diameter.

2d. "To contain not exceeding one-half (½) of one per cent dirt. (Material readily suspended in water.)

3d. "Not exceeding 12½ per cent to pass through a No. 80 Standard Cement Testing Sieve.

4th. "Not exceeding 50 per cent to pass through a No. 50 Standard Cement Testing Sieve.

"The sand shall be sharp.

SPECIFICATIONS FOR MORTAR MAKING.

1st. "Sand to be reasonably dry.

2d. "Cement to be accepted.

3d. "One volume cement to one volume sand.

4th. "Measure sand portion in dry mixing box.

5th. "Measure cement on top of sand.

6th. "Overcast twice with shovel, or more often if necessary.

7th. "Cast dry mixture of cement and sand through No. 5 sieve or screen.

8th. "Be sure incorporation is fully accomplished before adding any water.

9th. "Add water at part of wet mixing box remote from screen.

10th. "Add water slowly and gradually to prevent washing.

11th. "Hoe dry mixture slowly into water, avoid any stirring further than to uniformly wet the mixture.

12th. "Conform mortar mixing to progress of work so no mortar goes into wall after having been wet fifteen minutes.

13th. "Lay aside small batch of each mortar mixing to see how it sets in an hour or two.

14th. "Reject and throw out of all boxes or skips any mortar mixed too long.

15th. "Insist on all employes rigidly obeying instructions of inspectors, or else being at once discharged.

"Such stone as has been excavated prior to this date and has successfully stood the exposure of the past winter may be used, except such as is badly charged with imbedded chalk. No stone having a clearly defined seam of this chalk, with any indication of fracture, can be used. Stones with imbedded chert or flint may be used.

"Such stones as may hereafter be removed from the channel conforming to the requirements of the general specifications and also to the conditions of the second clause thereof, except as to previous exposure.

"No projection beyond the fair face of the wall exceeding three inches will be allowed, and no face joints wider than one and one-half inches."

It should be added in regard to the first paragraph quoted that wall construction was permitted in some cases after the channeling had been done and before the rock had been removed. Excavation, sufficient to develop the nature of the foundation, might be required, but it was expensive for the contractor. Later developments indicated that it would have been safer to have held to the original specifications.

Sand rejected on account of pebbles was accepted if screened through a ⅛-inch mesh. If rejected on account of loam or dirt, it was accepted if so washed that it stood the test; if rejected, but close to the limits for fineness without other objectionable features, it might be accepted if thoroughly incorporated with a proper amount of coarse sand. Dirt ranged from a fine sand to a flocculent loam. It was separated in testing by filtering and weighing, or by washing in a 15-inch test tube and measuring the dirt by scale, the former method gave correct results. The latter method was quicker, but the percentage obtained should be divided by a factor ranging from 1 to 4, dependent upon the nature of the dirt.

The controlling factor in a wall of this kind is the mortar, and the controlling factor of the mortar is the thorough incorporation of the dry materials. A mixture of the required richness, manipulated somewhat as directed above, can be relied upon to furnish a safe product.

The rock face projection was made a factor one-fourth of the thickness of the stone for one section.

Supplemental specifications, and instructions and definitions for the use of the assistant engineers were issued as required, some of which are herewith quoted:

"Samples of cement for testing shall be collected as follows: If in barrels, a sample shall be taken from every fifth barrel at random, or 30 samples per carload, evenly distributed through the carload lot. If in sacks, a sample from every tenth sack, or 30 samples per carload, evenly distributed through the carload lot.

"Samples should be taken, as far as practicable, from the interior of the package, rather than at the surface.

"Each warehouse will be provided with chests containing 90 small boxes, or sufficient for samples from three carloads. The numbers appearing on the boxes will be the numbers pertaining to the samples taken.

"Each box will contain a tag bearing also the number of the sample. The boxes should be completely filled with loose cement.

"Each warehouse will be provided with a book for the warehouse records as indicated therein. It shall be the duty of the inspector in charge to correctly and promptly enter the proper records therein.

"In the column of remarks he should daily enter the stock of cement on hand in the morning and the evening.

"The inspector of each warehouse shall closely examine all cement received, to discover that it complies with the cement specifications in all particulars other than that involved in the tests for strength.

"He should also be careful to note any damage to cement after it has been received and before it is distributed on the work.

"He should at once notify the assistant engineer of any unfit cement in stock.

"The inspector at the warehouse will be provided with a stock-book. When the contractor desires to move cement out of the warehouse to the work he shall apply to the inspector, who will fill out the blanks in stock-book as indicated, giving one filled blank to the contractor.

"The contractor in delivering the cement to the wall work shall also deliver to the inspector on the wall the filled blank he received from the inspector at the warehouse.

"It shall be the duty of the contractor to know at what stations on the work the cement is to be delivered, and inspectors are to be instructed not to deliver or receive any cement unless it is handled in strict conformity with these instructions.

"The term "joints" as used in previous specifications refers to the spaces between stones, without regard to the relative position of the surfaces of the stones.

"These spaces, or joints, must in all cases be filled with mortar.

"The mortar in joints on the face of the wall must be fair with the face of the wall as nearly as practicable, the deviation therefrom not to exceed one inch.

"The dimensions of joints shall be limited by the condition that it shall not be possible to find anywhere in the wall a cube of mortar exceeding three inches on a side."

In relation to the sampling of cement:—The contractor was expected to notify the warehouseman of the receipt of cement and it was then sampled as soon as possible. As the work progressed it became convenient to all concerned to sample the cement at the Chicago yards before shipping to the works, or to have an inspector located at the cement company's works who sampled the cars as they were loaded.

The warehouseman sent a printed postal card advising the testing laboratory of the shipment of cement samples. The re-

ceipt of the sample was acknowledged, the results of the tests and the reply card duplicating his record were exchanged. All upon postal card of convenient printed forms.

In addition to sampling and distributing the cement, it was also the duty of the warehouseman to keep records of the volume of sand delivered and to sample the same.

No instructions were issued regarding the coping. The conditions were such that had stone of the full width of the wall on the top been required, it would have entailed no extra expense to the contractor.

The general methods of work were as follows:

Slope stakes on the original surface were set for Main Channel excavation, their distance from the center line was based on a rock surface estimated from the data available; as the rock surface was developed, a toe stake was set for a one on one slope in earth cutting. This toe stake was one foot back of the back of the proposed wall. It controlled additional excavation, scabbling for wall foundation was limited to the back of the wall. No attempt was made to produce a full or uniform slope. The cutting was generally carried out to the required distance by steam shovels, cableways or other methods, and left without additional sloping.

A vertical bank was permitted in case the material would stand. Likewise a slope of four on one was required in one place on account of the nature of the material. In all cases the extreme slope combined with the actual cutting determined the limit for payments.

The scabbling of rock for wall foundations was necessitated by natural causes such as faults, fissures, shaly rock, weathering, etc., or by ledges being loosened and fractured by glacial action, channeling, blasting, etc. It was generally done with the pick and bar. Blasting was prohibited. The price paid for scabbling was the same as for Main Channel excavation and the yardage was included with the same.

The yardage thus removed on Sections 5 to 8 inclusive and the average depth of the same for the full width of the wall at its base is as follows:

Section 5. 7,128 cubic yards. Averaging 0.9 foot deep for full width of wall.

Section 6. 3,482 cubic yards. Averaging 0.6 foot deep for full width of wall.

Section 7. 2,361 cubic yards. Averaging 1.6 feet deep for full width of wall.

Section 8. 723 cubic yards. Averaging 1.0 foot deep for full width of wall.

Backfilling was accomplished by various methods: dumping direct from cableway skips, from cars on berm, by derricks in pit, etc., the material being taken from the Main Channel; also by wheelbarrowmen, scraper and derricks, etc., taking material from

the spoil banks. In case rock was used, the dumping of large fragments against the wall was prohibited. No payments were made for backfilling, the area being regarded simply as a spoil bank area. It will be readily observed by an inspection of the areas shown in Figure 1 that the backfilling required per yard of wall increases with the height of the wall. The ratio passes from 0.0 to 1 to 1 for a 6 foot wall, and to about 3 to 1 for a 40 foot wall. The relation is readily shown by comparing the equations for the theoretical wall and backfilling areas, when more than 8 feet in height, *i. e.*, $\frac{1}{4}$ h^2+16 = wall area and $\frac{3}{4}$ h^2+h-16 = area of backfilling in which h = height of wall.

In general, the method of quarrying was to use a guy derrick of from six to ten tons capacity, with a boom from forty to sixty feet long, operated by a hoisting engine, loading the stone on cars and delivering to the wall derricks. The use of explosives was limited to charges of black powder sufficiently strong to spring the ledge. It was an exceptional quarry that gave three consecutive strata of good stone.

Quarry spoil was of small volume and was generally removed by some of the Main Channel conveyors and used for backfilling.

The stiff leg wall derrick was of the same general capacity as the quarry derricks, having a mast from 25 to 30 feet high, and a boom from 35 to 40 feet long, it was moved on a track parallel to the wall by means of the hoisting engine, by which it was operated.

Complete data were not available to the writer for Sections 1 to 4 inclusive, when this paper was prepared, therefore tables I and II are based on the records of the assistant engineers, of the Sanitary District for Sections 5 to 8 inclusive.

The cost of scabbling or preparing foundation and of backfilling are not included in tables I and II, in which the cost of the wall covers everything from the cutting of the stone to the pointing of the wall inclusive, and of the quarry, everything after the selected ledge was stripped, up to and including the delivery of the stone to the wall derricks.

The amount for sand and cement applies only to the value of the material actually used. One sack of cement was regarded as containing two cubic feet, and the percentage of mortar for the one to one mixture was based on 75 per cent of the volume of the dry materials.

The typical plants employed show the machinery required when operations were advancing at a maximum rate on the various sections.

The items of cost given do not include the expenses of general superintendence, installation, and wrecking of machinery, materials for repairs, pumping, interest on capital invested, delays caused by strikes, lack of material, insurance of property or persons, storage, etc. Nor is any allowance made for salvage.

TABLE I.

TABLE SHOWING THE COST OF MASONRY RETAINING WALLS.

Items.	Sec. 5. Amount.	Sec. 5. Cost per cu. yd. Cents.	Sec. 6. Amount.	Sec. 6. Cost per cu. yd. Cents.	Sec. 7. Amount.	Sec. 7. Cost per cu. yd. Cents.	Sec. 8. Amount.	Sec. 8. Cost per cu. yd. Cents.	Totals. Amount.	Totals. Cost per cu. yd. Cents.
Wall	$ 48,596.97	90 0	$36,976.03	122.0	$ 7,667.42	124.0	$3,461.11	120.4	$ 96,701.53	103.3
Quarry	41,643.90	77 0	22,722.85	75.0	2,152.85	34.8	2,473.87	86.2	68,993.47	73.8
Cement	12,102.60	22.4	8,100.60	26.5	1.545.80	25.0	560.80	19.5	22,309.80	23.9
Sand	6,162.50	11.4	4,455.00	14.5	850.50	13.8	310.50	10.8	11,778.50	12.6
Totals	$108.505.97	200.8	$72.254 48	238 0	$12.216 57	197.6	$6,806.28	236.9	$199,783.30	213 6
Cubic Yards	54,077.8	......	30361.7	......	6179.9	......	2874.9	......	93,494.3	......
Percentage of Mortar	12.41	......	14.82	......	13.89	......	10.83	......	13.25	......
Length, right and left, feet	10,000	......	10,000	......	4676	......	3564	......	......	......
Average Height, feet	22.3	......	15.9	......	8.8	......	5.4	......	......	......
Average Area, square feet	146.0	......	82.0	......	35.6	......	21.5	......	......	......
Work Began	Sept, '94	......	Sept., '94	......	April, '95	......	May, '95	......	......	......
Work Ended	Oct, '96	......	Oct., '95	...	Nov., '95	......	Sept. '95	......	......	......
TYPICAL PLANT EMPLOYED.										
Hoisting Engine and Boiler	11	......	8	......	4	......	1	......	......	......
Guy Derrick	4	......	4	......	2	......	2	......	......	......
Stiff Leg Derrick	7	......	7	......	2	......	1	......	......	......
Revolving Derrick	....	......	1	......	....	......	....	......	......	......
Steam Drills	2	......	2	......	1	......	2	......	......	......
Air Drills	....	......	4	......	....	......	....	......	......	......
Air Hoist	....	......	4	......	....	......	....	......	......	......
Horse Power Hoist	....	......	....	......	....	......	2	......	......	......
Miscellaneous Tools	Set.	......	Set.	......	Set.	......	Set.	......	......	......
Estimated Value	$10,950	......	$12,825	......	$4 400	......	$2,035	......	$30,210	32.3
Total cost per cubic yard	......	......	......	......	......	......	......	......	......	$ 2.459

It should be added that in addition to the contract price of $3.25 per cubic yard for masonry, all excavation was paid for at Main Channel prices, including all quarry products.

Sand is rated at $1.35 per cubic yard and Louisville cement at 20 cents per sack.

Table II is based upon total time and amounts shown

Table II.

MASONRY RETAINING WALLS.

Itemized Table of Force, Percentages and Cost. Based on Sections 5 to 8 Inclusive.

WALL FORCE.

Classification.	Typical Force.	Rates per day of 10 hours each.	Percentage of Cost.	Cost per cu. yd. Cents.
General Foremen	....	$4.50 to $5.00	00.2	00.2
Foremen	1.00	4.00 to 4.50	10.9	11.3
Masons	4.20	3.25 to 3.50	34.2	35.4
Mason's Helpers	1.46	1.50	5.6	5.8
Mortar Mixers	1.81	1.50	7.1	7.3
Mortar Laborers	0.66	1.50	2.6	2.7
Hod Carriers	1.82	1.50	7.1	7.3
Derrickmen	1.77	1.50	6.9	7.1
Enginemen	1.00	2.00 to 2.50	5.2	5.4
Firemen	0.06	1.75	0.3	0.3
Laborers	1.62	1.50	6.3	6.5
Water boys	0.45	0.75 to 1.00	0.9	0.9
Teams and Carts	0.86	3.50 & 2.50	7.5	7.8
Blacksmiths	0.07	2.00 to 3.00	0.2	0.2
Blacksmith's Helpers	0.06	1.75	0.	0.1
Carpenters	0.09	2.25 to 2.50	0.5	0.5
Carpenter's Helpers	0.02	1.75	0.0	0.0
Machinists	0.04	3.00 to 4.50	0.3	0.3
Derricks	1.59	1.25 to 1.75	4.0	4.2
Totals	16.99 (men)		99.9	103.3

QUARRY FORCE.

Classification.	Typical Force.	Rates per day of 10 hours each.	Percentage of Cost.	Cost per cu. yd. Cents.
General Foremen	0.01	$4.50 to $5.00	00.2	00.2
Foremen	1.00	3.00 to 4.00	10.6	7.8
Derrickmen	2.11	1.50	10.1	7.5
Quarrymen	8.42	1.65	42.2	31.2
Enginemen	1.10	2.00 to 2.50	7.0	5.2
Firemen	0.04	1.75	0.2	0.2
Laborers	2.28	1.50	10.9	8.0
Water boys	0.33	0.75 to 1.00	0.9	0.7
Blacksmiths	0.27	2.00 to 3.00	1.7	1.3
Blacksmith's Helpers	0.18	1.75	0.9	0.7
Carpenters	0.02	2.00 to 2.50	0.1	0.0
Carpenter's Helpers	0.00	1.75	0.0	0.0
Drill Runners	0.36	1.75 to 2.00	3.1	2.3
Drill Helpers	0.07	1.50	0.4	0.2
Watchmen	0.04	1.50	0.1	0.1
Machinists	0.00	3.00 to 4.50	0.0	0.0
Teams and Carts	0.29	3.50 & 2.50	3.8	2.8
Derricks	1.12	1.25 to 1.50	5.4	4.0
Drills	0.36	1.00 to 1.25	2.1	1.5
Totals	16.52 (men)		99.7	73.7

Fig. 522. Main Channel. General view of the Quarry Face.

Fig. 523. A Portion of Finished Wall.

in above table. The typical force is based upon 1 foreman, the total number of days for wall foremen being 2,525, and f r

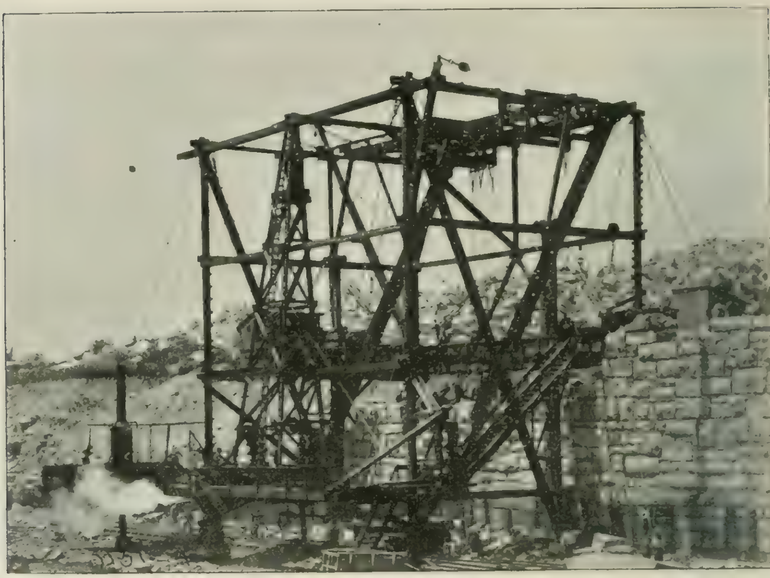


Fig. 524. The "Williams" Wall Derrick.

Fig. 525. Excavation of a "Pocket."

quarry foremen, 2,212. The average yardage built per day by the wall force was 37.0 cubic yards. The average of wall laid by one mason was 8.8 cubic yards. The cost per cubic yard for the typical force at the minimum rates shown is $1.05, against $1.03 in the column of cost per cubic yard.

The services of a general foreman and of a fireman were exceptional. Rates for machinery cover the cost of coal, oil, waste, etc., and the estimated value of steam or air for drills.

Fig. 522 shows a general view of a quarry face main channel.

Fig. 523 shows a portion of finished wall on Section 5; the space left for the operation of a Main Channel drainage pump was filled in upon the completion of excavation.

Fig. 524 is a view of the Williams wall derrick used on Section 4, and shows the platform and cement store-house of the same. This derrick shows the principal departure from the methods generally followed, and upon which the above tables are based. It was designed and operated by Mr. Benezette Williams, formerly chief engineer of the district, and showed remarkable capacity. Fig. 525 illustrates the excavation of a "pocket" to be filled with masonry on Section 13.

CONCRETE WALLS.

The contract and specifications for concrete retaining walls are found in the printed proceedings of the sanitary district on page 2135, and supplemental agreement on page 2958 for Section 15, and on page 3346 for Section 14.

The requirements for sand and cement are similar to those previously quoted. Payment for backfilling and for excavation was made on Section 14, the contractors for this work not being the general contractors for the section.

A sectional area of the concrete wall is practically the same as for the masonry wall except that the top width is six instead of four feet. A coping and facing of Portland cement mortar three inches thick was required to be placed before either the mortar or concrete had taken an initial set. The facing extended down the face of the wall fourteen feet or to an elevation of—9.0 feet Chicago City Datum, requiring five cubic feet of Portland cement mortar for each lineal foot of wall: Portland cement used on Section 14 was 9.3 per cent of the total cement used and on Section 15, 5.2 per cent. The average height of wall for Section 14 was about 10 feet, and for Section 15 about 22 feet, thus making the Portland mortar a considerably larger per cent of the total on Section 14.

Fig. 526 shows a plan sketch of the work and location of machinery on Section 14, and suggests, in connection with the typical force, the general method of work. An Austin jaw crusher discharged the unscreened stone directly into the receiving bin of the Sooysmith mixer, both machines were mounted on the same flat car, the cement, sand and stone were raised from their respective bins by means of belt conveyors running at the same

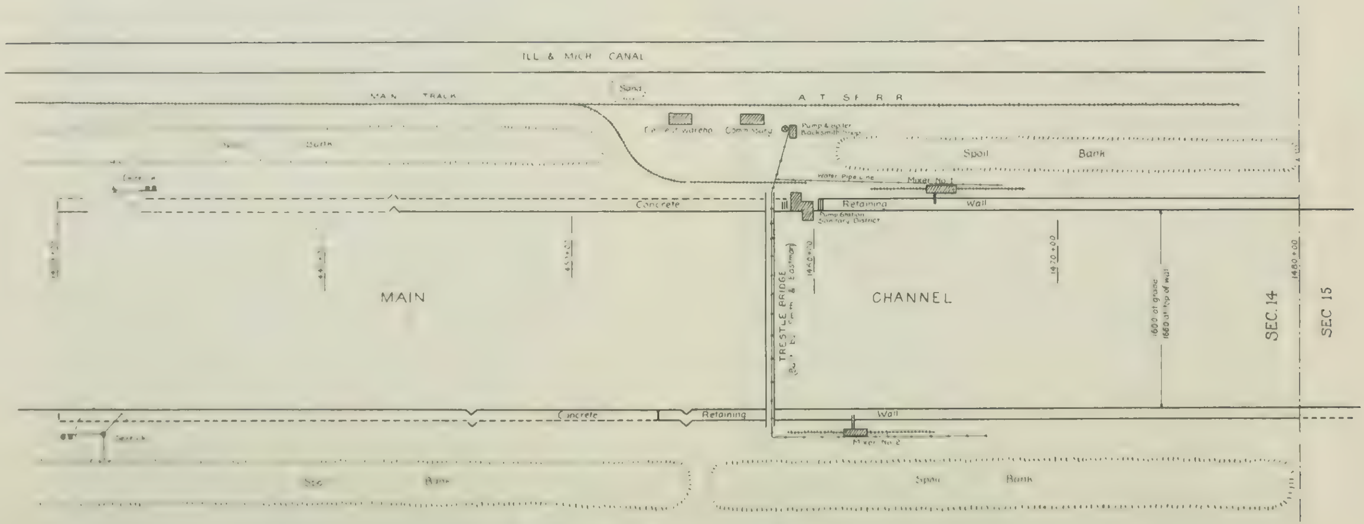


Fig. 526. Plan of Section 14.

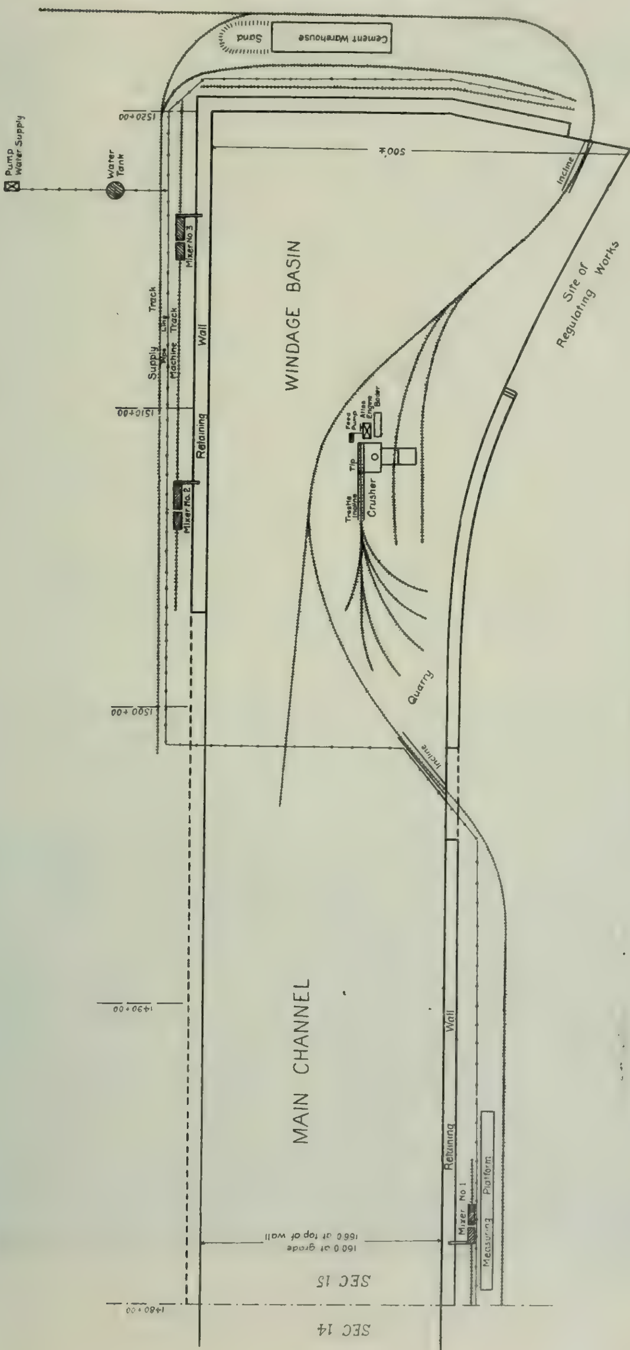


Fig. 527. Plan of Section 15.

rate of speed but carrying buckets spaced proportional to the required ingredients. Stone was conveyed from the spoil bank to the crusher by wheelbarrowmen. Cement and sand were hauled by teams and dumped directly into the mixer bins.

Fig. 527 shows a similar sketch of the work on Section 15. The quarry is within the Main Channel limits and about 1,000 feet from the No. 7 Gates crusher, on to the tipping platform of which the loaded cars were drawn by a cable hoist. The average output of the crusher for a day of 10 hours was about 210 cubic yards. The transportation of materials to the mixer was effected by a standard gauge light locomotive and Petla dump cars of about four and one-half cubic yards capacity water measure. The mixer consisted essentially of a spiral screw rotating in a trough, mixing and depositing the ingredients on a rubber belt conveyor running over concave pulleys. The water was applied by a spray pipe as the mixer discharged the material upon the conveyor. The mixer was operated by an engine and boiler mounted upon a separate car. The entire apparatus was moved along its track by means of a block and tackle operated by a winch on the engine.

Fig. 528 shows the crusher on Section 15 and the quarry in the background, at the left of which is a section of finished wall.

Supports for the concrete forms were made by setting vertical posts about nine inches in front of the face of the

Fig. 528. General View of Section 15.

wall and eight feet apart; an iron dowel pin set three or four inches into the rock held the foot of the post in place;

TABLE III.

CONCRETE RETAINING WALLS. SECTION 14.

Itemized Table of Force, Percentages and Cost.

Nature of Work	Classification of Labor.	Typical Force.	Rates per day of 10 hours each.	Percentage of Cost.	Cost per cu. yd. Cents.
General	Superintendent	1.0	$4.00 to $5.00	2.7	2.6
	Blacksmith	1.1	2.50 to 3.00	1.7	1.6
	Timekeeper	0.5	2.50	0.7	0.7
	Watchmen	0.6	2.00	0.7	0.7
	Waterboys	3.9	1.00	2.3	2.2
Wall	Foremen	0.9	$2.50	1.3	1.3
	Laborers	8.6	1.50	7.5	7.3
	Tampers	2.3	1.50 to $1.75	2.3	2.2
Mixing	Foremen	1.2	$2.50	1.8	1.7
	Enginemen	1.8	2.00 to $3.00	2.6	2.5
	Laborers	6.7	1.50	5.8	5.7
	Pump Runners	1.0	1.75 to 2.00	1.1	1.0
	Mixers	1.7	1.25	1.2	1.2
Timbering	Foremen	0.6	$2.50	0.8	0.8
	Carpenters	4.7	2.00 to $3.00	5.8	5.7
	Laborers	1.2	1.50	1.0	1.0
	Helpers	5.3	2.50	7.7	7.5
Transportation	Foremen	0.0	$2.50	0.0	0.0
	Laborers	2.6	1.75	2.6	2.6
	Teams	6.3	3.00 to $3.50	11.9	11.6
Crushing	Foremen	0.5	$2.50	0.7	0.7
	Enginemen	1.7	2.00 to $3.00	2.4	2.3
	Laborers	3.5	1.50	3.3	3.2
	Crusher	1.7	1.20	1.1	1.1
Quarrying	Foremen	1.7	$2.50	2.4	2.3
	Laborers	32.9	1.50	28.7	28.0
Totals		90.6 men		100.1	97.5

MATERIALS.

Cement, Utica	86.3
Cement, Portland	30.5
Sand	46.5

PLANT VALUES.

2 Crushers	$3,000		
2 Mixers	3,000		
Track	1,260		
Lumber	500		
Pipe	840		
Sheds	400		
Pumps and Boiler	600	$9,600	40.7

Total estimated cost per cu. yd $3 015

Table IV.
CONCRETE RETAINING WALLS, SECTION 15.
Itemized Table of Force, Percentages and Cost.

Nature of Work.	Classification of Labor.	Typical Force.	Rates per day of 10 hours each.	Percentage of Cost.	Cost per cu. yd. (Cents.
General	Superintendent	1.0	$5.00	2.5	2.4
	Blacksmith	0.9	2.50	1.1	1.1
	Waterboys	4.5	1.00	2.2	2.2
	Teams	1.7	3.00 to $3.50	2.6	2.5
Wall	Foremen	1.1	$2.00	1.0	1.0
	Laborers	14.4	1.50	10.6	10.5
	Tampers	0.1	1.50	0.1	0.1
Mixing	Foremen	2.1	$2.50	2.6	2.6
	Enginemen	2.1	2.00 to $2.50	2.2	2.2
	Laborers	23.1	1.50 to 1.75	18.1	18.0
	Mixers	2.1	2.25	2.2	2.2
Timbering	Carpenters	0.8	$3.00 to $3.50	1.3	1.3
	Helpers	10.2	2.50	12.5	12.4
	Laborers	0.7	1.50	0.5	0.5
Transportation.	Foremen	0.7	$2.50	0.9	0.9
	Enginemen	1.4	2.00 to $3.00	1.9	1.9
	Firemen	0.4	1.50 to 1.75	0.3	0.3
	Brakemen	2.2	1.75 to 2.00	1.9	1.8
	Teams	0.4	3.00 to 3.50	0.7	0.7
	Laborers	1.5	1.50	1.1	1.0
	Locomotives	1.4	2.25	1.5	1.5
Crushing	Foremen	1.0	$2.50 to $3.00	1.4	1.4
	Enginemen	1.0	2.50 to 3.00	1.4	1.4
	Firemen	1.0	1.50 to 1.75	0.8	0.8
	Laborers	11.1	1.50	8.2	8.1
	Crusher	1.0	2.25	1.1	1.1
Quarrying	Foremen	1.0	$2.50 to $3.00	1.2	1.2
	Drillmen	1.8	2.00	1.8	1.7
	" Helpers.	1.8	1.50	1.3	1.3
	Laborers	19.0	1.50	14.0	13.9
	Drills	1.8	1.25	1.1	1.1
Totals		107 (men)		100.1	99.1

MATERIAL.

Powder (quarrying)	8.3
Cement, Utica	93.0
" Portland	18.0
Sand	47.6

ESTIMATED VALUES.

1 Crusher	$12,000		
Use of Locomotive	2,200		
Cars and track	5,300		
3 Mixers	3,000		
Lumber	1,200		
Pipe	720		
Small Tools	1,000	$25,420	56.7

Total estimated cost per cu. yd. $3.227

wooden braces held the posts in place longitudinally and tie rods connected them with a line of similar posts at the back of the wall. The forms were sixteen feet long and two feet wide, dressed on one side; they were set as the work advanced, and were held in line by wedges.

Two one-foot courses of concrete were laid, and after an interval of about twenty-four hours the forms were drawn, cleaned, and set for the succeeding courses. A loose link passed around the post and through a block supporting the bottom of the form and acting as a friction clutch. The Portland cement facing was placed by using plates of iron held by blocks three inches from the forms; as the course was completed this plate was withdrawn and the union between the mortar and concrete thoroughly tamped.

The combination of one part of screenings with two parts of sand could be used as sand.

In tables III and IV the typical force is based upon a superintendent as a unit. The total force does not include machinery. Rates for machinery cover the cost of coal, oil, and waste only. The estimated values of the plant makes no allowance for salvage. The installation and wrecking of plant, delays caused by strikes or lack of material, insurance on property or persons, storage, repairs, interest on investment, etc., are not included in cost prices. Utica cement is rated at 65c per bbl.; Portland, at $2.25, and sand at $1.35 per cubic yard.

The contract prices per cubic yard on Section 14 were: Excavation, 38c; concrete masonry, $2.74; backfilling, 14c; and on Section 15 the concrete masonry was $3.40.

The total yardage involved on Section 14 was 23,568, and on Section 15, 44,811. The average daily output of the two types of machines was practically the same, being about 100 cubic yards per day of ten hours each. The concrete was composed of two parts of cement to three of sand to eight of broken stone; the Portland mortar was a one to three mixture. The structure is a monolithic mass; no attempt was made to predetermine vertical cracks.

The inspecting force for each section on both masonry and concrete work consisted generally of a head inspector in charge, a warehouseman, and as many inspectors on mortar and wall as the plants operated by the contractors required.

The assistant engineers in charge of the work were Mr. Hiram A. Miller, to October, 1895, and Mr. Chas. L. Harrison, to August, 1897.

DISCUSSION.

By L. K. Sherman, Mem. W. S. E.

Mr. Beardsley's paper furnishes valuable data on the relative cost of concrete and rubble masonry. Rubble masonry is shown

to be the cheaper, provided stone is quarried at the site of the work, but on Secs. 14 and 15 no building stone was found and rubble would have cost more than concrete.

The cost of plant per cubic yard given under the heading of "Plant Used," seems too great. This cost is a difficult thing to determine. I understand that the large crusher used on Sec. 15 is still in operation, and hence some allowance should have been made for salvage on the same in the table presented.

In regard to the concrete wall; this was built in a continuous mass, without vertical contraction joints. Cracks have developed on the Portland mortar coping of the wall. In work of this class the Portland finish should be bonded on before the concrete has an initial set, and joints cut to predetermine the lines for contraction.

The contraction cracks, however, do not extend into the concrete or show on the vertical face of the wall. In no instance on the 20,000 lineal feet of concrete wall has the Portland finish on the vertical face of the wall shown any tendency to scale off. Th s finish was laid up with the concrete and not plastered on.

WRITTEN DISCUSSION.

By Chas. L. Harrison, Mem. W. S. E.

Mr. Beardsley gives instructive and useful data. Their value, however, depends to a great extent upon a knowledge of the conditions which obtained when the work was done. Because this work was done at a given price it would not do to conclude that rubble masonry and concrete masonry could be built for the same price under different conditions. The tabulated statement of cost and force employed gives a good basis for estimating work under different conditions, as the cost is given for each part of the work.

On contract Sections 12 and 13 there existed a number of "clay pockets," which extended generally from the surface of the ground to and below the grade of the channel. A rubble masonry wall was constructed at each of them under the same specifications as given in Mr. Beardsley's paper. The amount of masonry in each "pocket" varied from 200 cu. yds. to 2,000 cu. yds, but generally between 400 cu. yds. and 600 cu. yds. This masonry was built with guy derricks erected at the pockets and moved from place to place as the work progressed; while on Sections 5 to 8 the derricks used traveled on a track laid for that purpose. In all other essential features the methods of working were the same. The amount of masonry built on these two sections was something over 20,000 cu. yds. Allowing salvage of about 50% on the plant used the cost was as follows:

Building, including plant, labor and materials	$1.651 per cu. yd.
Quarrying, including plant, and labor for quarrying the stone and delivering it at the building site........................	0.632 " " "
Miscellaneous expense.....................	0.095 " " "
Total cost...........................	$2.378 " " "

If the entire cost of the plant is included the total cost becomes $2.82 per cu. yd.

The information concerning the concrete masonry is interesting from the fact that very few data exist as to the cost of building large quantities of such masonry in continuous walls. The data for the two sections (14 and 15) are presented in the same form, making it easy to compare the cost in detail. Tabulating the separate items of cost as given in the itemized tables for each section we have:

	Sec. 14. cost in cents per cu. yd.	Sec. 15. cost in cents per cu. yd.		Sec. 14. cost in cents per cu. yd.	Sec. 15. cost in cents per cu. yd.
General	7.8	8.2	Cement, natural	86.3	93.0
Wall	10.8	11.6	" Portland	30.5	18.0
Mixing	12.1	25.0	Sand	46.5	47.6
Timbering	15.0	14.2	Plant	40.7	56.7
Transportation	14.2	8.1			
Crushing	7.3	12.8			
Quarrying	30.3	*27.5			
Total	97.5	107.4	Total	301.5	322.7

The work on the two sections was done by two different contractors and in some particulars under different conditions. It will be noticed that there is a material difference in the cost of some of the items and it is of interest to know whether this is due to the management of the work or to conditions which would legitimately make this difference in cost. The first two items in the table agree very closely, but the third item, *mixing*, costs about twice as much on Sec. 15 as it does on Sec. 14. The reason for this may be found in the machines used for mixing the materials and the division of costs of mixing and quarrying in each case. With the machines used on Sec. 14 the materials were delivered into bins, and then carried in buckets, attached to chains, to the mixer proper, the entire apparatus being driven by an engine and requiring only one or two laborers to look after it; while on Sec. 15 the materials were delivered at the machine on a platform and then shoveled into the mixer proper. The cost of this latter process is included, in part, in the cost of quarrying on Sec. 14, as will be seen later on.

*Includes 8.3 cents per cubic yard for explosives.

The cost of *timbering* on the two sections is practically the same. The slight difference may be accounted for by the difference in the average height of the wall.

Transportation of materials on Sec. 14 costs 14.2 cents while it costs 8.1 cents on Sec. 15. On the former they were hauled in wagons by teams, and on the latter in cars by locomotives. It is probable that the cheapest method was used on each section under existing conditions. The sand and cement were delivered on to the mixer for Sec. 14 while they were dumped on to a platform alongside the mixer for Sec. 15, making more work in the former case than the latter.

Crushing costs 7.3 cents on Sec. 14 and 12.8 cents on Sec. 15. This difference may be due in part to the kind of crushers used and in part to the sizes of stone furnished to them.

Quarrying costs 30.3 cents on Section 14 and 27.5 cents on Sec. 15. It includes all the cost of securing the stone and delivering it to the crusher. On Section 14 the stone was taken from the adjacent spoil bank, giving a haul of less than 100 feet generally. At some points this rock was in such large pieces that it was necessary to use the sledge a great deal, making it cheaper to haul smaller stones several hundred feet with teams. On Section 15 the stone was quarried from the main channel and conveyed in cars to the crushers partly by team and partly by cable hoist. If the cost of blasting (8.3 cents) be deducted from the cost of quarrying on Section 15 we then have a cost of 19.2 cents as given by Mr. Beardsley. This perhaps is a fair comparison as we begin with the rock broken up in each case. It will be seen that the quarrying on Section 14 includes delivering the stone on to the crusher and mixer and the mixing on Section 15 includes shoveling the materials from a platform on the ground into the mixer. The division is therefore not the same in each case. However, if we neglect the cost of explosives on Section 15 and in each case consider the mixing and quarrying as one item we have a cost on Section 14 of 42.4 cents and on Section 15, 44.2 cents. Taking the entire cost of all the above items (except explosives) we have 97.5 cents and 99.1 cents, which shows substantially the same cost for the work on the two sections. The difference in cost per cubic yard of wall built for the two kinds of cement used is explained by Mr. Beardsley.

The plant on Section 14 costs 40.7 cents and 56.7 cents on Section 15. More plant was required on Section 15 than on Section 14. On the latter section it was all new while on the former it was second hand. The difference in cost was due in part to the requirements of the work and in part to the difference in condition of plant when installed. The cost of such work will vary with the conditions so that it is important to know as much of the conditions as possible before making an estimate of cost.

LVI.

BERTHIER METHOD OF COAL CALORIMETRY.

By Chas. V. Kerr, Mem. W. S. E.

(*Read November 2, 1898.*)

Of late years engineers have paid considerable attention to the question of determining the heating power of the fuels used by them. The heating power of the two chief combustible elements of fuels, carbon and hydrogen, having been determined with great accuracy by scientific men years ago, the obvious method was to analyze the fuel, ascertain the proportions of carbon and hydrogen and then calculate the heating power. But to practicing engineers such analyses are quite out of the question, and the services of expert chemists are nearly as costly as those of the engineer himself. For such reasons and from a desire to determine by direct measurement the results of combustion the plan has been devised of burning the fuel in an atmosphere of oxygen, absorbing in water the heat evolved, thus directly measuring the heating power of the various combustibles in the fuel without reference to their relative proportions and under conditions not radically different from those existing in the actual furnace. But the apparatus for exact work is more or less costly and the skill of a physicist is necessary to manipulate it satisfactorily, and to make the various corrections, chiefly that for radiation. Nevertheless, this method is theoretically the ideal one, and is most in favor.

It is the purpose of this paper to present some of the claims to favor of a method which was proposed and used as many as seventy years ago. In the interval the method has been used more or less, but when described by scientific writers the description has usually included a denunciation based on its alleged theoretical inaccuracy. It has survived, however, largely on account of its practical convenience.

An eminent French mineralogist and member of the Academy of Sciences, Pierre Berthier, was born at Nemours, France, in 1772. In 1833, he published in eleven volumes his chief work, "A Treatise on Assays by the Dry Method." In Volume I of this work he describes his method of finding the heating power of fuels as follows: "Mix intimately 1 part by weight of the substance, in the finest state of division, with at least 20, but not more than 40, parts of litharge. Charcoal, coke or coal may be readily pulverized; but in the case of wood the sawdust produced by a fine saw or rasp must be employed. The mixture is put into a close grained conical clay crucible, and covered with 20 or 30 times its weight of pure litharge. The crucible, which should not

be more than half full, is covered and then heated gradually until the litharge is melted and evolution of gas has ceased. At first the mixture softens and froths. When the fusion is complete, the crucible should be heated more strongly for about ten minutes, so that the reduced lead may thoroughly subside and collect into one button at the bottom. Care must be taken to prevent the reduction of any of the litharge by the gases of the furnace. The crucible, while hot, should be taken out of the fire and left to cool; when cold, it is broken, and the button of lead detached, cleaned and weighed. The accuracy of the result should be tested by repetition."

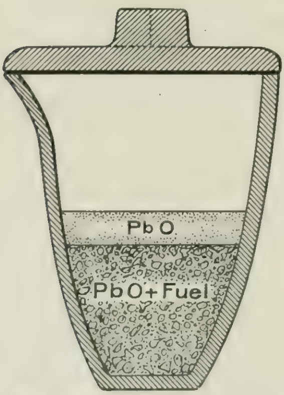


Fig. 529. Clay Crucible with Charge Ready for the Furnace.

(Use about 50 grams of PbO to one gram of coal, and cover with about 25 grams PbO.)

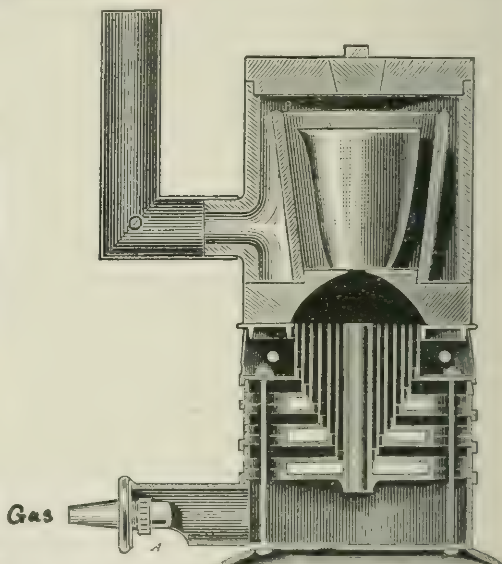


Fig. 530. Furnace for Heating the Crucible in Berthier Method.

The litharge, or "stone silver," as the name signified to the alchemists, used in this process is an oxide of lead, PbO, formed by heating metallic lead in contact with air. If this oxidation takes place below the melting point of the oxide, the result is a dull yellow amorphous powder, called "massicot," which has the same composition, PbO. It melts at a red heat, forming a dark red transparent liquid. In the crystallized state following melting it has a buff color. The commercial litharge is often mixed with red lead, Pb_3O_4, which is formed by heating massicot in air, or even with a small amount of finely divided metallic lead. Consequently, care must be taken to secure chemically pure litharge, intended for assayer's use. This has a dull lemon yellow or buff color.

In using litharge in clay crucibles a *bright* red heat should be avoided, because the liquid litharge combines with silica at a high

temperature, forms a fusible silicate of lead, and soon perforates the crucible. This property occasions the use of litharge in the manufacture of glass and in glazing earthenware. The purpose of covering the mixture of fuel and litharge in the crucible with a quantity of pure litharge is not only to prevent access of air to the fuel but also to prevent the escape unoxidized of the more volatile portions of the fuel. And this covering of pure litharge must likewise be protected from the furnace gases. A yellow flame like that of a gas jet would reduce the litharge to lead in the oxidation of the incandescent carbon of the flame; while the blue flame of a Bunsen burner would have no such effect. Some have not only covered the crucible, but luted it with clay to keep out the furnace gases. This is rather foolish than wise, since the gases, CO_2 and H_2O, formed in the crucible during the oxidation of fuel and reduction of lead must be allowed to escape or an explosion will ensue. The simple precaution necessary is to put on the crucible the usual clay cover to prevent particles of fuel falling in or an incandescent flame coming in contact with the litharge, which would cause the reduction of metallic lead.

Berthier based his method on what is known as Welter's law, which he expressed thus: "It has been proved by the experiments of many philosophers that the quantities of heat emitted by combustible substances are exactly proportioned to the amounts of oxygen required for their complete combustion." Thus, a pound of carbon burning to carbonic acid gas, CO unites with $2\frac{2}{3}$ times its weight of oxygen and evolves 14,600 heat units, or pounds of water raised one degree Fahrenheit.

$$C+O_2=CO_2 \quad (1)$$
$$12+32=44$$
$$\frac{O_2}{C}=\frac{32}{12}=2\tfrac{2}{3}$$

And the heat evolved will be $14{,}600 \div 2\frac{2}{3} = 5475$ heat units per pound of oxygen used. If the oxygen is furnished by litharge, the chemical changes will be shown by the equation:

$$2PbO+C=CO_2+2Pb \quad (2)$$
$$2\,(206.9+16)+12=44+413.8$$
$$\frac{2Pb}{C}=\frac{413.8}{12}=34.48$$

Now, by Welter's law, if the heat evolved is proportional to the oxygen used it must also be proportional to the weight of lead reduced. For each unit weight of lead the heat evolved will be $14{,}600 \div 34.48 = 423.4$ heat units. Then the combustion of F pounds of fuel will evolve $423.4 \times \frac{L}{F}$ heat units per pound, in which L=weight of metallic lead reduced, and F weight of fuel used.

But, unfortunately, Welter's law does not hold true for hydrogen compared with carbon.

$$2\ H_2+O_2 = 2\ H_2O \qquad (3)$$
$$2\times 2.02+32=2\ (2.02+16)$$
$$\frac{O_2}{2H_2} = \frac{32}{4.04} = 7.92.$$

A pound of hydrogen evolves 62,000 heat units. Hence the heat per pound of oxygen used will be 62,000÷7.92= 7,830 heat units. This compared with the 5,475 in the case of the carbon shows too great a difference to be due merely to errors of observation. So that in this simple form, the Berthier method must give incorrect results when used with fuels containing unknown mixtures of carbon and hydrogen. The method has, therefore, been generally discredited. The following from Poole's "Calorific Power of Fuels" is a fair summary of the adverse criticism: "This formula was recommended by Berthier and has been used since by a few others. It is faulty, as was shown by some of Berthier's own determinations in which contradictory results were obtained. Dr. Ure showed that no uniform results could be obtained using the same materials. Scheurer-Kestner in 1892 showed that the formula not only gave erroneous results, but actually reversed the relation of combustibles. * * * This method is allowable only in cases where the crudest approximations are desired and where no analyses or calorimetric tests can possibly be made."

With the fundamental theory shattered and such a load of adverse criticism to carry, it is apparently useless to investigate the Berthier method further. Nevertheless, it may be possible that a method of coal calorimetry correct in theory may on account of experimental errors give more widely varying or more erroneous results than one defective in theory, but freer from errors of experiment. That is the opportunity of the Berthier method.

When it is stated that the heating power of one pound of carbon is 14,600 B. T. U. and of hydrogen 62,000, we are to understand that the combustibles are to be taken at 32° Fahr. under atmospheric pressure, and that the products of combustion, carbonic acid gas and water, are to be returned to that temperature and pressure. If the hydrogen of a fuel is oxidized by reduction of litharge, the chemical changes will be represented by the equations:

$$PbO+H_2=H_2O+Pb \qquad (4)$$
$$222.9+2.02=18.02+206.9.$$

And the lead reduced per unit weight of hydrogen will be

$$\frac{Pb}{H_2}=\frac{206.9}{2.02}=102.42$$

Then the ratio of lead reduced per unit weight of hydrogen to that per unit weight of carbon will be 102.42÷34.48=2.97. Consequently, if Welter's law were true, the heating power of hydro-

gen would be 14,600x2.97=43,362 B.T.U.; while it is actually greater than this by 62,000—43,362=18,638 B.T.U. A fuel containing 2 per cent by weight of hydrogen, as in the case of coke, charcoal or anthracite, if judged by the formula

$$P=423.4\frac{L}{F} \qquad (5)$$

would be in error by $18,638\times.02=373$ heat units. Then the constant, 423.4, must be increased by $373\div34.48=10.8$, making it to the nearest unit, 434, and the formula will be

$$P=434\frac{L}{F}$$

If the fuel contains an average of 5 per cent hydrogen, as in the case of bituminous coal, lignite and wood, the error will be 18,638x0.05=932 heat units; and the correction to the constant will be $932\div34.48=27$, making the formula

$$P=450\frac{L}{F} \qquad (6)$$

The percentage of hydrogen in the fuels named is so nearly constant that the formulas (5) and (6) are probably within 1.5 per cent of the correct value. If the proportion of hydrogen in a particular fuel is known, then the constant can be modified in the manner shown so as to give exact values. But the error in sampling alone is liable to be much more than 1.5 per cent.

Sulphur exists in almost every fuel in small but widely varying proportions and it has a heating power of about 4,500 B.T.U. per pound. It has not been considered as a combustible, however, for the reason that it occurs usually as iron pyrites, $Fe\ S_2$, which must be dissociated before the sulphur can act as a combustible, the net result in heat units being doubtful.

When fuel is burned in the ordinary boiler furnace a large excess of air is usually present and the products of combustion are sent into the chimney at a high temperature. It may be of interest, therefore, to consider here the heat actually available in what is at present called good practice. Assume 18 lbs. of air at 32° F., and normal pressure, an excess of about 50 per cent, to be required for the combustion of each pound of fuel, and that the products of combustion together with the excess of oxygen and nitrogen to enter the chimney at a temperature of 400° F. Then the loss of heat to the carbon burned will be about 1,600 heat units, the total carried away by the carbonic acid gas, the oxygen and the nitrogen. While the hydrogen will lose almost 15,000 heat units, more than half of which is due to the latent heat carried away in the aqueous vapor or steam. The available heat then will be

for carbon, 14,600—1,600=13,000 B. T. U.
for hydrogen, 62,000—15,000=47,000 B.T. U.

TABLE I.

BITUMINOUS COAL.

No.	Fuel.	Weight of Coal Grams.	Time of Fusion.	Weight of Lead Button Grams	Calorific Power B. T. U.	Average.
1	Huntington Fancy Lump.	1.8293	15 min.	55.9698	13,034	
2	"	2.0495	15 "	61.8461	12,855	12,935
3	"	2.0338	15 "	61.6578	12,915	
4	Pittsburg, Kan., Mine Run	1.182	8 "	29.994	10,823	
5	"	1.0525	13 "	26.781	10,852	
6	"	1.318	12 "	33.166	10,732	10,735
7	"	1.414	13 "	34.914	10,531	
8	Ft. Smith, Ark., Mine Run	1.0019	13 "	28.4048	11,915	
9	"	1.4385	21 "	41.0555	11,995	11,960
10	"	1.2005	12 "	34.1865	11,970	
11	Baldwin, Ark., Lump....	0.8819	12 "	23.626	11,260	
12	"	1.0594	13 "	28.5725	11,335	11,307
13	"	0.9950	22 "	26.8144	11,327	
14	Fayetteville, Ark., Lump	1.2285	15 "	34.1030	11,870	
15	"	1.4895	15 "	40.6995	11,485	
16	"	2.0625	15 "	57.3645	11,690	11,586
17		1.6335	15 "	44.680	11,500	
18	Kansas Lump.	1.127	15 "	29.4332	11,230	
19	"	1.015	15 "	26.9328	11,150	
20	"	1.019	15 "	27.1331	11,190	11,220
21	"	1.0625	15 "	28.5901	11,310	
22	Huntington, Ark., Slack.	1.9968	15 "	52.2333	11,143	
23	"	2.0335	15 "	53.5909	11,227	11,060
24	"	1.8686	15 "	47.4247	10,812	
25	Ind. Territory Mine Run.	1.115	20 "	22.697	8,682	
26	"	1.162	20 "	23.239	8,529	8,636
27	"	1.382	20 "	28.158	8,696	

TABLE II.

*COMPARISON OF OXYGEN AND LITHARGE METHODS.

No.	Fuel.	Wt. Fuel Grams.		Heating Power.		Results.		Probable Error. Per Cent.	
		Oxy.	Lith.	Oxy.	Lith	Oxy.	Lith.	Oxy.	Lith.
1		......	2.18	Calibration.	14,640	Calibration.	All.		
2	Carbon from	......	1.882		14,820		14,330	0 Det.	6 Det.
3	Granulated	......	1.879		14,550		.....	....	....
4	Sugar.	......	2.767		13,920		1,2,3,6	±2.6	±0.76
5	Ash, 0.44%.	......	2.919		13,590		14,617	....	....
6		......	1.937		14,480		.....	....	....
7	Bituminous	1.310	3.197	14,720	11,420	......	......	....	....
8	Slack from	1.377	2.306	14,090	11,530	......	......	....	....
9	West Vir-	1.468	3.453	14,520	11,460	14,620	11,470	±1.1	±0.14
10	ginia.	1.204	3.502	14,320	11,520	......	......	....	....
11		0.812	2.877	15,460	11,420	......	......	....	....
12	Anthracite	1.328	2.4535	12,660	13,560	......	......	....	....
13	Coal from	1.372	2.3165	12,370	13,650	......	......	....	....
14	Lehigh Val-	1.394	2.0000	12,520	13,604	12,760	13,616	±1.7	±0.08
15	ley.	1.538	2.0000	12,230	13,622	......	......	....	....
16		1.262	2.9675	14,000	13,643	......	......	....	....

*From Thesis work of Mr. L. H. Flanders at the Armour Institute of Technology.

The excess of available heat in the hydrogen over that required by Welter's law will be $47,000 - 13,000 \times 2.97 = 8,390$ B. T. U. The formulas will then be

$$P = \frac{13,000}{34.48} \times \frac{L}{F} = 377\frac{L}{F}, \text{ for pure carbon.} \quad (7)$$

$$P = \left(377 + \frac{0.02 \times 8,390}{34.48}\right)\frac{L}{F} = 382\frac{L}{F}, \text{ for fuel with 2 per cent hydrogen.} \quad (8)$$

$$P = \left(377 + \frac{0.05 \times 8,390}{34.48}\right)\frac{L}{F} = 389\frac{L}{F}, \text{ for fuel with 5 per cent hydrogen.} \quad (9)$$

The advantage of formulas (8) and (9) is that they enable the evaporation of water per pound of fuel by a boiler plant in good condition to be directly determined. Thus, if a fuel gives a value of $L \div F = 30$, then $P = 389 \times 30 = 11,670$ B. T. U. per pound of bituminous coal, If steam is formed at 100 pounds gauge from feed water at 202° F., the heat put into each pound of steam will be 1,014 B. T. U. Hence the evaporation should be $11,670 \div 1,014 = 11.5$ pounds of steam per pound of dry coal.

The tables of calorimetric tests of various coals given herewith are intended to illustrate the degree of uniformity in results that may be expected with ordinary care and skill Part of this work was done by students and part by the writer. The heating power of the bituminous coals was calculated some years ago from the formula $P = 430\ L \div F$. The determination of the heating power of charcoal derived from granulated sugar was made to show how much confidence would be supported by results of experiment on a fuel of known heating power. Favre and Silberman give 14,544 B. T. U. for pure carbon; while Berthellot says 14,647 B.T.U. Both of these figures are averages of results of experiments by these skilled physicists on a fuel of constant heating power.

It was intended to compare the results by the Berthier method with results by the oxygen calorimeter on a number of fuels. But the form of instrument available, even with the greatest care, gave such widely varying results that the comparison is not satisfactory.

In regard to the cost of material for calorimetric tests by the Berthier method, the clay crucibles will cost about 4 cents each, and the charge of about 100 grams of litharge about 2½ cents. So that if five determinations are made for a given fuel the total cost of material will be about 33 cents. A suitable furnace and a chemist's balance are supposed to be available.

WRITTEN DISCUSSION.

By J. C. Bley, Mem. W. S. E.

The Berthier method, as presented by Prof. Kerr, appears to be likely to prove satisfactory in practice when the chemical

composition of the coal is known. But there is an element of uncertainty with a strange coal. No method of estimating the chemical percentages is given other than chemical analysis, and that is ruled out because too expensive, except by classification as *bituminous*, *anthracite*, etc. If we are to get our percentages from this rough estimate, why not save the trouble of trying to measure the heat altogether by taking published tests that are much more easily obtained?

Unless some method is available to enable a practical engineer to determine the relative proportions of the principal elements, as carbon and hydrogen, directly from a sample of unknown coal, the Berthier method would appear to leave him in doubt over the result.

CLOSURE.

By C. V. Kerr, Mem. W. S. E.

In reply to Mr. Bley, I would first call attentionto the apparent fact that hitherto in the use of the Berthier method no attempt has been made to correct for the error due to the greater relative heating power of hydrogen. There is a remarkable uniformity in the percentages of hydrogen in bituminous coals from different localities as given in published analysis. It is seldom that the amount is outside a range of from 4.5 to 5.5%. The formula given is based on 5% hydrogen, so that the error in the use of that formula is probably well within the error in selecting a sample of a given coal—an error which is common to all methods, even to a chemical analysis. The corresponding statement is true of anthracite coal.

There are undeniably theoretical errors in the Berthier method, but the purpose of this paper is to point them out and indicate a correction for them. On the other hand, the experimental errors of the oxygen methods, due to corrections for radiation, specific heat of vessel, etc., and to measurement of rise in temperature of the water used to absorb the heat of combustion of sample, are so large that the Berthier method may actually be more accurate.

The difference in heating power of coal from different mines, even in the same field, is frequently so large that the suggestion of relying on published tests of calorific powers can hardly be accepted when it is possible to directly determine it for a given case by either the oxygen or litharge methods.

LVII

TRACK ELEVATION OF THE PITTSBURG, FT. WAYN & CHICAGO RAILWAY.

By W. H. Coverdale, C. E.*

Presented informally Nov. 9, 1898.

I listened with a great deal of interest to the papers presented upon the subject of Track Elevation at the former meeting, and I am very glad to contribute in a small way to the general information which is being collected on this subject.

The ordinance under which the track elevation of the P., Ft. W. & C. Ry. was done, was passed in July, 1896. The work was begun in the latter part of July, 1897, and during the year of 1897 the retaining walls were very largely built, and the foundations for the abutments were put in, but no sand filling whatever was done. The work was stopped early in October, 1897, with the masonry partly completed.

The district through which this work has been carried on is the Englewood district of Chicago, as shown on the plan, Fig. 531. The northern limit is at Fifty-first street, and from that point the work extends along an approach of about 2,500 feet to our first subway at Fifty-fifth street, or Garfield boulevard. We then run 1.4 miles to State street and from there we decline on an easterly approach 3,500 feet long. On the approach to the north end we have about 27 tracks. We have elevated in all, or partly elevated rather, 14 miles of track on the different approaches, and 5.6 miles of main track on the principal part of the elevation. The work of this year was begun on the 12th day of March, and it has been carried on to a practical completion at about the 19th day of October. On that date all of our track work was finished; all of our masonry was completed; and there remains to be done but a very little of the subway work. One of the principal reasons why that was not finished is that we were very largely dependent upon the different departments of the city and they were exceedingly busy on the south side during the summer; hence we could not at all times have the interest taken in our work by the City which we felt it deserved. We are, however, just about completing the work now. The water pipes and all underground work which is handled by the city has been completed and we will finish the entire work very shortly.

Fig. 532 shows the method followed on this work. In general it is very similar to the descriptions which you have already had from the gentlemen who have preceded me upon this subject.

*Engineer of Track Elevation Pittsburg, Ft. Wayne & Chicago Ry.

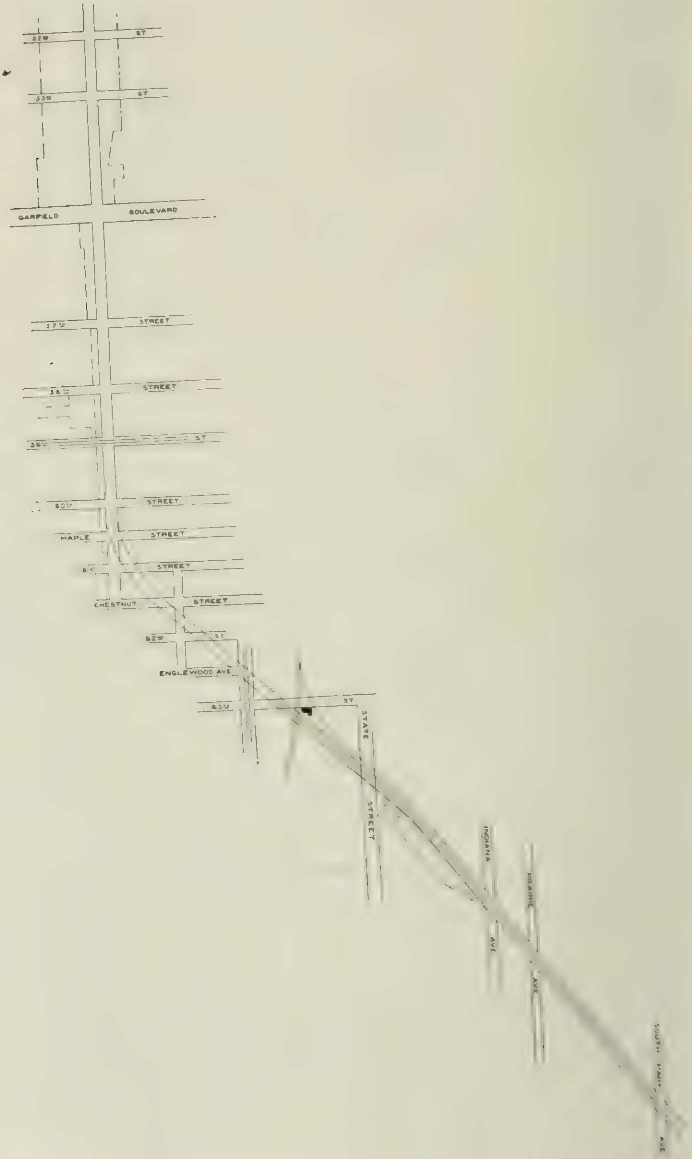


Fig. 531. Map of the P., Ft. W. & C. Tracks Through Englewood District.

The main difference is that instead of using piling, as was done on the Northwestern, we have erected timber bents, consisting of two upright lines of posts, six feet center to center, cross caps on the tops of the posts and longitudinal caps on the cross pieces. To permit of the abutments being built between the bents themselves and the timber cribs, the trestles were erected and the girders were built upon them.

The right of way of the Pennsylvania Company through this district is about 66 feet wide and four tracks were laid upon that right of way. The method of procedure was to elevate the two westerly tracks first. Inasmuch as the right of way was of such width, it was found impossible to put these tracks up to their height without encroaching on the clearance of the two east tracks that were used as running tracks. This was obviated in the middle of the blocks by raising the running tracks under traffic. Towards the eastern end of our work, where the bridges were close together, the minimum distance being about 200 feet, it was found impossible to put in any appreciable amount of sand filling between these bridges, although the running tracks were raised in the center of the block. The reason why the running tracks were not raised across the street is that we were anxious to keep those streets open to the city traffic as much as possible. We were very earnestly requested by the fire department to help them in every way possible, and we found it very little trouble to accede to a large extent to their request.

We put up the three west girders upon trestle bents and immediately upon erection did a little excavating underneath, so as to permit the passage of fire engines, giving them a clearance of about eleven feet. This would not have been possible if the two running tracks had been raised at the streets. It was, therefore, necessary to obtain some sort of a temporary crib in the immediate vicinity and at the ends of all these approaches. At the easterly end of the work this crib, built of old ties, was carried from one bridge to the next. The height of the crib was perhaps eight feet, and it was put up at very little expense and taken down at a cost somewhat greater, because we had to dig in to the sand filling for the ties. After the permanent structure was erected, we took the ties out as far as was at all possible. The girders weighed from twenty-five to forty tons, or about 1,000 pounds per lineal foot for the heaviest. The weight of the girders being so considerable, it precluded the possibility, as we thought, of doing the work in any more expeditious manner than the one finally decided upon. Two girders were loaded upon cars and were blocked up high enough to clear the longitudinal caps of trestles. They were handled with a derrick car, one end at a time, and when once upon the trestle they were swung over upon a greased rail, which rested upon the top cap. The floor was afterwards put in with the derrick car, which stood upon one of the easterly running tracks. When two girders were

Fig. 532. Showing Method of Erecting Bridges.

Fig. 533. Erecting 63d Street Bridge.

Fig. 534. Tie Cribbing for Retaining Fill.

brought to the bridge site, we generally occupied from thirty minutes to two hours in getting the girders off the car and having the main track cleared for traffic.

Fig. 533 shows the Sixty-second street bridge; the clear span is twenty-five feet, the length of the girder is fifty-two feet, owing to a bad skew. The style of trestle bent is different from the others on account of the lesser weight of the bridge. The angle was about 36 degrees to the street line.

As soon as the girders were erected we immediately put in a tie crib and started the sand filling. The longest distance which we have between any of our bridges is about 1,100 feet between Fifty-fifth and Fifty-seventh streets; the average distance between bridges is about 600 feet. Under these conditions, and in order to obviate the necessity of putting in switches at each block, we started the work at one end, put up a bridge, followed it up with tie cribbing and sand filling and did as much work as possible before putting up the next bridge. We put up the first bridge about the first of May and about the 9th of June we had our trains running over the two westerly tracks. At Wentworth avenue the track was not elevated until a later date for the reason that the street cars were on that street and we were anxious to keep them running as long as possible. We depended very largely here upon the co-operation of other interests, besides our own, and on this account Wentworth avenue and Fifty-ninth street were not erected as soon as the remaining bridges. Our State street and Sixty-third street bridges were the only two bridges which were erected upon the masonry without the use of trestle bents. At State street, owing to a change of alignment, we were able to build about two-thirds of our masonry and swing in four girders. We have five tracks across State street and we were able to put three of them in place without the use of any timber trestle whatever.

Fig 534 illustrates the tie crib that I spoke of on the short blocks east. The distance between these two bridges is about 300 feet, and the degree of curvature is about four degrees and forty minutes. We were at that time running over the two westerly tracks. The trestle bent is about twenty-eight feet long and was built for two tracks. As soon as we had the traffic started on the westerly tracks, we began at the south end of our work to put up our bridges for the easterly tracks. We put up a trestle bent on the east side for a single track bridge, allowing the cars with the materials loaded upon them to be brought out on our remaining track; we erected these two girders on the left hand side in a manner precisely similar to the one in which the girders were erected on the right hand side of the picture and closed all traffic on the track by backing out with the derrick car and setting the buckle plate on the floor behind the car.

Fig. 535 is the diagram showing the bridges in a very general way. The girders are seven feet high; this height is uniform on all the bridges with the exception of a very small square opening,

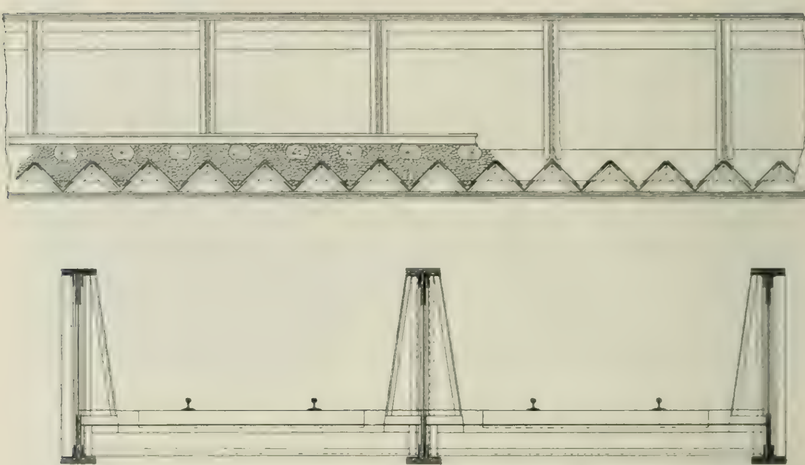


Fig. 535. Longitudinal Section and Cross-Section of Bridge Floor.

a twenty-five foot span, at Fifty-eighth street. The girders at this point are four feet high; all other girders are of the uniform height of seven feet. The web plates of our girders consist of five-eighths inch soft steel and the top and bottom flanges are reinforced by cover plates, three of them on the middle portion of girders. These plates are sixteen inches wide and three-quarters of an inch thick. The floor is of the pattern shown; angle lugs are riveted to the sides of the girders, which are shown here on the diagram, and upon these lugs or brackets the floor is placed. This floor weighs about 500 pounds per lineal foot and is of rectangular section. The object in this floor was not so much shallowness as it was quietness. We were anxious to obviate, as much as possible, the noise of trains passing over bridges, and this floor was chosen with that very largely in view. It was the original intention to have the base of rail about one-half inch above the apex of these floor troughs. We found, however, that the results under these conditions were not so good as we had hoped for and it was then decided to raise the tracks on the bridges an additional 6 inches. The base of rail is now just $6\frac{1}{2}$ inches above the apex of the trough. The track is carried through the bridges on stone ballast precisely the same as on embankments, and the result is improved since we raised the track the additional six inches. The clearance is thirteen feet, center to center of girders on the tangent, and fourteen and one-half feet, center to center of girders on the curve. The maximum degree of curvature is about 4 degrees and 40 minutes, and the minimum is 1 degree and 30 minutes.

Fig. 536 shows Fifty-ninth street upon the day that the bridge was erected; the street car tracks have just been cut. This is shown to illustrate the typical bridge, showing the timber

Fig. 536. Erecting Bridge at 59th Street.

Fig. 537. Track on 55th Street Bridge.

Fig. 538. Subway at 59th Street.

bents at the end; the tie crib is in the course of construction. This also illustrates the floor system which was used, but that is shown by the diagram.

Fig. 537 illustrates the track on Fifty fifth street bridge. This is the longest bridge we have, 200 feet, and the picture was taken, as you will notice, very shortly after the traffic had been put over the bridge. The track is not in line and not in surface, but it shows you the ballast on the bridge, which is carried over level at the top of the ties until it strikes the girders.

Fig. 538 is a typical sub-way at Fifty-ninth street after the street car tracks had been depressed. The average depression of the streets was perhaps four feet, rather less than that, however, at this point.

Fig. 539 shows the easterly approach to the track elevation work. It is about 3,500 feet long, and the picture was taken at South Park avenue looking westward.

Fig. 540 shows the masonry which we have been putting into our retaining walls. This picture was taken at our State street subway. The walls in general are from nine to eleven feet in height. The quantity of rubble masonry in these walls is about 19,000 cubic yards; the quantity of concrete in the foundation is about 15,000 cubic yards; the number of lineal feet of coping on these walls is 15 000. We had about 60,000 cubic yards of excavation from the subways and foundations; about 500,000 cubic yards of sand filling; about 15,000 cubic yards of ballast; about 4,500 cubic yards of abutment masonry. 40,000 barrels of cement were used on the work. The weight of the iron is about 5,000 tons. The weight of the different bridges varies from 270 tons to 780 tons; Fifty-fifth street viaduct, being the long bridge, weighs the most; that weight is 780 tons, and the smallest is Fifty-eighth street bridge.

Fig. 541 is a view taken on the day that the Western Society of Engineers went over the work on the inspection trip. It is looking north, and the bridge immediately in the foreground is the Fifty-ninth street bridge. The general appearance of the work is indicated here—not at all well, however. We used Bedford stone for coping, and the stone was sawed to uniform thickness and has a good line on the back. The center of the track is about eleven feet from this coping, and the toe of our ballast is about four feet from the rail. The intervening space has been filled with black cinders and presents a neat appearance. The entire space between the tracks is filled up to a uniform level with the top of the ties with crushed limestone. The right of way upon the Englewood curve cannot be used to such good advantage for the reason that the tracks are fourteen and one-half feet, center to center, instead of thirteen; on this account the ballast encroaches very near to the line of the retaining wall, in fact we lose the effect of the black cinders entirely when we come to Sixty-first street.

Fig. 539. Track Looking West from South Park Avenue.

Fig. 540. Masonry of Retaining Walls at State Street Subway.

Fig. 541. Elevated Tracks, Looking North from 60th Street.

Fig. 542. General Appearance of the Elevated Roadbed.

Fig. 542 is another view taken on the same day, showing the tracks as they were at that time, and a train running about thirty miles an hour on the bridge. The tracks are not on their final alignment. They appear rather rough, but the picture illustrates very well the general appearance and character of the work.

One very interesting phase of the work, which I had hoped to hear discussed, is the joint work with the Rock Island at Sixty-third street. The Rock Island tracks crossed the Fort Wayne tracks at a somewhat acute angle at Sixty-third street, and in such a manner that we could not put up our bridges without cutting out Rock Island traffic, nor could they erect their structures without interfering with the Fort Wayne traffic in a similar manner. This was due to the fact that the alignment of both the Rock Island and Fort Wayne Companies was altered at this point in such a manner as to prevent the Rock Island people from setting their masonry without interfering with our tracks and our setting our masonry without interfering with their tracks. This was overcome by the plan of elevating the tracks upon the old location and on temporary sand filling. As soon as this was done we were each to abandon one track in order that each company might have a single track across on the new alignment. It was found possible, however, for the Fort Wayne Company to so adjust their tracks that the Rock Island people could have a double track over the new crossing. On our part, on the Sunday upon which this change was made, we erected a temporary trestle, so that we ran over the bridge with one track and over a temporary bent with another track. The work was done in a somewhat expeditious manner and with the hearty co-operation of the Rock Island people. During the process of the elevation of tracks at this point we had at no time more than thirty minutes of continuous work, the traffic being very heavy over the Rock Island tracks and somewhat heavy over our own. The work was done

jointly and was carried on as opportunity presented itself. Sunday was our big day, because there were considerably less trains that day than on week days. On the Sunday on which the transfer was made to the new tracks the old alignments were abandoned at 1:40 and the track immediately torn up. At 2:30 about four trains had passed over the new tracks. The Rock Island had both their tracks ready at that time, and the Fort Wayne tracks were in such condition that we were erecting the second span of the bridge, with our main line traffic going over the permanent structure.

LVIII

TRACK ELEVATION OF THE ST. CHARLES AIR LINE.

By H. W. PARKHURST, Mem. W. S. E.

(*Read November 9, 1898.*)

The St. Charles Air Line Railroad extends from the Illinois Central tracks to the west side of the South Branch of the Chicago river, and is located between Fifteenth and Sixteenth streets, in the city of Chicago. It was originally built as a straight line, with the exception of the curve at the east end connecting it to the Illinois Central tracks. In its course, it crossed at grade, Indiana, Michigan and Wabash avenues, State, Dearborn and Clark streets, and the network of tracks between Clark street and the South Branch of the river. It was, therefore, of great importance to the traffic of the city streets to have this double track road elevated, and not less important was it to reduce the complications of the grade crossings between the several railroads east of Clark street.

The earliest plans for the elevation of the St. Charles Air Line were made in June, 1895, and for two and one-half years the matter was under discussion between the owners of the St. Charles Air Line Road, the city authorities, and the representatives of the railroads interested in the crossings west of Clark street. Plan after plan was formulated, discussed and rejected, and numerous conferences were held between the city officials and the managing officers of the various railroads.

Finally an ordinance, which was practically agreed to by all companies, was passed by the City Council May 17th, 1897, was approved by the Mayor May 22d following, and within the specified time, the same was accepted by the railroad companies interested.

The St. Charles Air Line is owned by four companies,—the Illinois Central, the Chicago, Burlington & Quincy, the Chicago & Northwestern, and the Michigan Central railroads, each having an undivided one-quarter interest. West of Clark street the railroads interested were the six tenant companies of the Chicago & Western Indiana, the Atchison, Topeka & Santa Fe, the Chicago, Rock Island & Pacific, the Lake Shore & Michigan Southern, and, indirectly, the Chicago & Alton Company.

The crossings between the tracks of these several companies constituted one of the most complicated network of tracks within the city limits. It was thought that no solution of the problem would be satisfactory which retained the existing grade crossings between these railroad tracks. One solution was suggested, which, by depressing certain tracks, raising another set to a compara-

Fig. 543. View Between two Retaining Walls, I. C. R. R.

Fig. 544. Track Looking East from Indiana Ave.

Fig. 545. East Abutment.

tively slight elevation, and the third set of tracks to a very high elevation, did away with all of the grade crossings between railroads; but this introduced such extraordinarily steep grades into the St. Charles Air Line and Chicago, Madison & Northern connections, that it was deemed impracticable. The plan finally adopted depresses the tracks of the Western Indiana and Santa Fe railroads, so that no street or railroad grade crossings exist for these tracks. The St. Charles Air Line and the Rock Island and Lake Shore tracks are raised to a uniform level, and the grade crossings formerly existing between the tracks of these companies are still maintained.

The elevation of the St. Charles Air Line tracks was, therefore, no simple problem, involving, as it did, material changes in the tracks used daily by more than a dozen other railroads.

In connection with the elevation of the St. Charles Air Line, the Illinois Central Company has also constructed an eastern approach to the same, shown in Figs. 543, 544 and 545. This is built entirely on ground belonging to the Illinois Central Company. As now being executed, the plan provides for viaducts carrying the St. Charles Air Line across the several streets between the Lake and the South Branch of the river, without any depression of any street up to Clark street. The situation at Clark street is somewhat complicated. As originally located, the St. Charles Air Line crossed Clark street only a few feet south of the crossing of the Santa Fe and Western Indiana tracks. In order to remove all grade crossings from Clark street (which was one of the prime factors in the problem of track elevation), the St. Charles Air Line has been diverted to the south, while the Western Indiana and Santa Fe tracks have been moved to the north. The St. Charles Air Line tracks have been elevated, the other tracks depressed, and Clark street passes under the Air Line tracks and over the Santa Fe and Western Indiana tracks with gradients not exceeding five per cent.

It was realized that the interests involved in the work west of Clark street were too numerous and complicated to be handled by a representative of any one railroad company. This work was, therefore, placed under the charge of an Advisory Board of Engineers, with Major G.W. Vaughn, resident engineer, in charge. The work east of Clark street has been handled by the regular organization of the Illinois Central Railroad, in the interest of the four owners of the St. Charles Air Line, the writer being in immediate charge of all details of the work.

After making comparative estimates of the cost of constructing elevated tracks on steel superstructure throughout, or of building them on embankments constructed between retaining walls with steel superstructure only across streets and alleys, it was determined to adopt the latter plan of construction, and proposals were received for the masonry work involved. Bids were made

Fig. 546. Looking West from Michigan Avenue.

Fig. 547. Looking West from Indiana Avenue.

for concrete, rubble, and cut stone retaining walls, abutments, etc. As favorable proposals were made for constructing the various street abutments of first-class bridge masonry, (Figs. 546 and 547) and the retaining walls of second-class coursed ashlar, backed with derrick rubble (Figs. 547 and 548), a contract was finally made for work of the latter character. Including the concrete foundations, there are about thirty-five thousand yards of masonry of all kinds in the work. The stone for

the work has been derived from two sources, the sandstone quarry at Williamsport, Indiana, and sandstone from the Berea quarries near Cleveland, Ohio. While these differ from each other in color—the Williamsport stone being a buff, and the Cleveland stone being of a grayish blue—there is little difference in the quality of the stone. Pains have been taken to use stone of the same kind for the opposite abutments at street or railroad crossings.

Stone has been laid by three different styles of derricks:

1st. Traveling derricks, illustrated in Figs. 543, 546 and 547, and in 548, each having two derricks mounted on a framework, built wide and high enough to span two tracks, and allow trains to pass under them.

2d. Stationary or stiff-legged derricks, which are illustrated in Fig. 544.

3d. A car derrick, which is illustrated in Fig. 549.

The general plan of carrying on this masonry work was as follows: The original tracks of the St. Charles Air Line lay generally on the southerly side of the strip of land belonging to the proprietors. This made it feasible to put in short sidings along the northerly side of the main tracks, adjacent to the site of the north retaining walls, Fig. 546. It should be added here that these retaining walls are constructed along the extreme borders of the property owned by the Air Line proprietors, which is a tier of lots from fifty to fifty-two feet in width, extending from Dearborn street to the alley between Michigan and Indiana avenues. East of this point a curved strip forty feet wide, located on a twelve degree curve, was the available territory owned by the proprietors, and west of Dearborn street, a strip thirty feet wide was the original right of way, which was increased by the purchase of property on the south side of the same and east of Clark street for the diversion of the St. Charles Air Line. West of Clark street some exchange of territory was arranged for with the Lake Shore and Rock Island railroad companies, so that the necessary diversion of the Air Line might be made. Owing to the location of the main tracks on the southerly side of the right of way, it was feasible to construct the north retaining wall in certain of the blocks without interfering with the operation of the road. (See Fig. 546) As fast as sections of this wall were completed, together with the adjacent ends of abutments at the several streets and alleys which were crossed by the Air Line, a trestle work was constructed to carry an elevated track on the extreme north line of the Air Line property. (See Figs. 549 and 550.) This was completed to a connection with an elevated track over Clark street, without stopping the traffic on the southerly of the two original tracks on the surface of the ground. At the same time certain sections of the south retaining wall had been constructed, and the foundation for the greater portion of the southerly wall had been put in. The traffic was then changed to the elevated

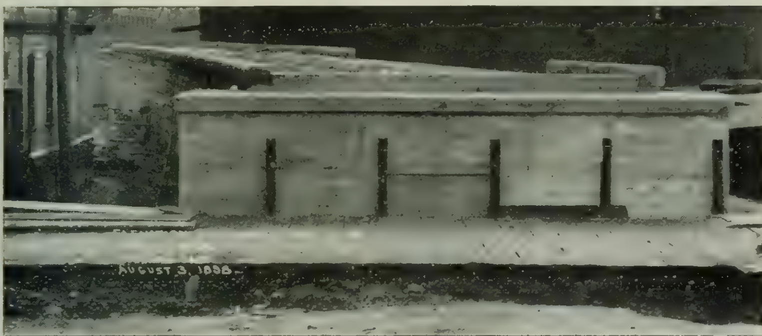


Fig. 548. Concrete Abutment at Clark Street.

Fig. 549. Looking West from Michigan Avenue.

track, and is now being operated over the same, while the remaining sections of the south retaining wall and the unfinished portions of the street and alley abutments are being completed. In handling this portion of the work, the abutments at State street were completed first, and through travel on the low grade track was cut off. Switch connections, however, were maintained from the east and from the west up to the back sides of the abutments at State street. The remaining sections of retaining wall are now being completed, working both east and west from State street.

As soon as the trestle work was constructed along the north side of the Air Line, the work of filling was begun. Slag has been used for this purpose. It has been received in the ordinary

gondola cars, and also in side-dumping cars; and very shortly after the elevated track was put in operation for the business of the Air Line, the space underneath this track was entirely filled with slag, and, from time to time, the stringers and caps have been removed from the trestle work, the filling has been widened out, an additional track has been laid in two of the blocks and the filling is nearly completed in the same. It is proposed to continue this method of carrying on the filling until its completion.

The east approach to the St. Charles Air Line is an embankment on a one per cent grade, about two thousand feet long, built between masonry retaining walls and terminating in an abutment about one hundred and twenty feet long on the east side of the Illinois Central main and suburban tracks. The work on this approach is illustrated in Figs. 543, 544 and 545. Fig. 545 shows the east abutment, and Fig. 543 shows a view between the two retaining walls after the slag filling has been partially made, with the same traveling derrick in the distance. This approach is wide enough for two tracks.

Access is had to the elevated tracks of the St. Charles Air Line west of Indiana avenue by means of an incline, starting at the Illinois Central suburban tracks and rising with a grade of 2.85 per cent to the east side of Indiana avenue. For this section of the elevation there will be three tracks, two having the full elevation and connecting with the two tracks on the east approach by means of the bridge over the main and suburban tracks of the Illinois Central Railroad, (Fig. 545) the third track being the inclined track already referred to (Fig. 544). The two main tracks, already referred to, will separate into four tracks just east of Michigan avenue, and four tracks will be carried over all streets and alleys to the west side of Dearborn street. At this point the four tracks will converge into two tracks, and these two tracks will extend across Clark street, across the Lake Shore and Rock Island Railroads and to and across the St. Charles Air Line bridge over the South Branch of the river.

At its western end the St. Charles Air Line crosses the South Branch of the Chicago river by means of a double track draw, about three hundred feet long. This draw has been raised and tilted on a grade approximating one per cent in order to connect the elevated tracks in the vicinity of Clark street with the Chicago, Burlington & Quincy and the Northwestern tracks on the west side of the river. Fig. 551 shows the draw standing on its protection during the process of elevating. This was done entirely by means of jacks placed under the panel points and under the center and the turntable rim. The turntable rim and track were tied together by means of suspension bolts; the track, wheels, etc., were elevated entirely clear of the masonry, being raised about five feet at first, and then a temporary timber support was put in. Meantime the west approach to the draw

Fig. 550. Looking West from Wabash Avenue.

Fig. 551. Raising Draw Span across Chicago River.

was graded up in a temporary way and timber work was put in to support the ends of the draw, when swung. A timber curb was built up under the turntable track. In this condition the draw was operated for several weeks, while such portions of the center pier and the abutments on each side of the river were built, the raising of the masonry being done by constructing concrete work in sections, the timber work being moved and rebuilt as was necessary in order to permit construction of the masonry. The

draw span rests upon the turntable by means of six castings. The bearing on the center pin was originally designed as a rocking bearing. Hence, in order to tilt the draw to the required grade, it was only necessary to make new castings, having such differences in thickness as would conform to the proper grade. Certain floor beam and stringer connections which were attached to the turntable drum, had also to be cut loose and readjusted and again riveted up, After operating the draw as stated, on its temporary wooden bearings for several weeks, it was again swung into line up and down stream, raised the additional amount (about fifteen inches), required to bring the center to the true line of the grade. It was tilted by the operation of jack screws; lowering at one end and raising at the other; the weight was taken off the turntable drum, and the new castings were inserted. Meantime the masonry of the abutments was completed to the proper grade, the masonry underneath the center bearing on the center pier was built up, as was also the concrete around the outer edge of the pier underneath the wheel track. After allowing this to set for two or three days, the draw was turned and the bearings at the ends were placed, and the connections of the floor beams and track stringers are now being adjusted at the center, so that the draw will be ready for operation tonight.

The general style of superstructure across the streets is illustrated in Fig. 552, which gives merely a cross-section of one girder

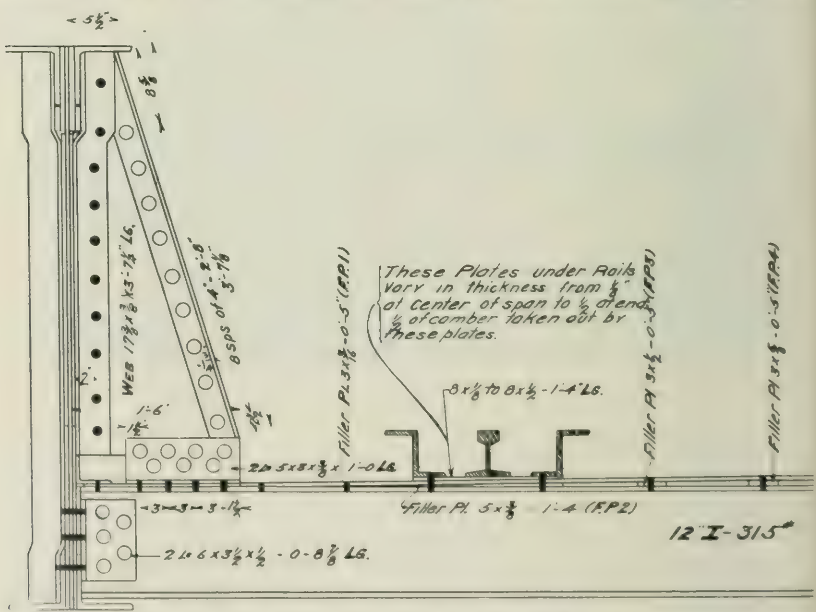


Fig. 552. Half-Cross-Section of one Girder of Bridge Floor.

and a portion of the floor. Posts are erected at the curb lines of the several streets, dividing the spans across these streets into three portions. There are independent girders over the streets and sidewalks, which are, however, riveted to a common post, standing at the curb lines. In most cases the girders over the sidewalks, as well as those over the alleys, are of deck construction. The girders over the streets are through girders with shallow floors. The floors are made of 12-inch I-beams. spaced generally, 12-in. center to center, covered with a 3/8-inch plate, carrying the rails on special short plates and having Z-bar guard rails on each side of each rail.

A complete system of gutters and down-spouts is constructed to receive the drainage from the floors and to take the same to the gutters in the streets. All streets and alleys will be re-paved. Catch basins will be placed in all gutters and sewer connections provided. A tile drain has been laid along the base of each retaining wall and connections are made through the foundations of the abutments to the street sewers, thus taking care of all water which might otherwise accumulate between the retaining walls.

LIX

JOINT TRACK ELEVATION AND DEPRESSION AT SIXTEENTH AND CLARK STREETS, CHICAGO.

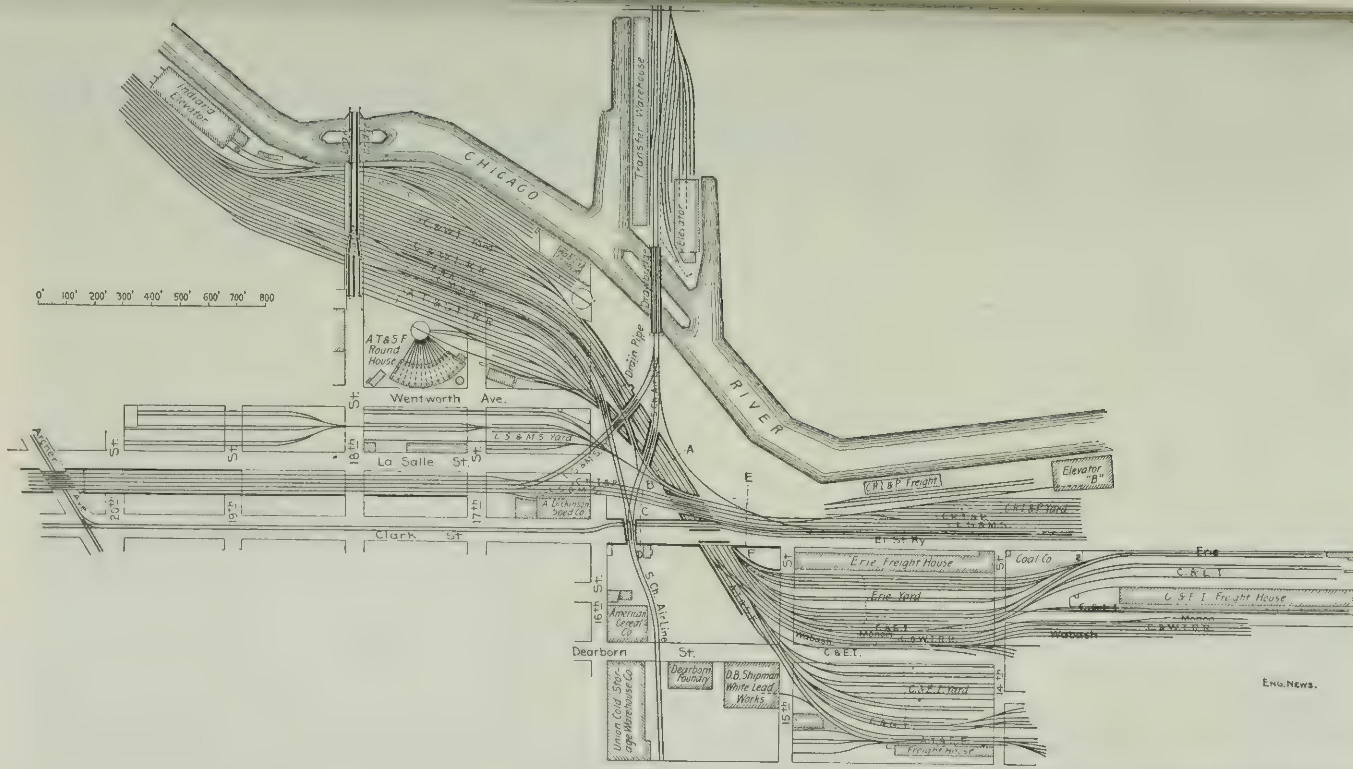
G. W. Vaughn, M. Am, Soc. C. E.*

As considerable interest has been manifested in this work by all classes of railroad men who were at all familiar with the complicated nature of the conditions under which it was undertaken, the following brief and necessarily incomplete account, detailing some of the difficulties and complexities under which it was carried out, may be of interest. The diagram on Fig. 553 will serve to make clear to you in some degree the network of tracks in the field under review between 15th and 16th streets, as they existed on the first of March last. The distance between those streets was about one thousand feet, and bunched together in that space and covered by a radius of three hundred feet were found one hundred and thirteen rigid crossing frogs, and near by were seven slip switches for the use of the various lines of tracks of the fifteen different railroads crossing here.

The roads within this field were the Lake Shore & Michigan Southern, with two main tracks and seven switching tracks; the Rock Island, with two main tracks and one switching track; the Chicago & Western Indiana, with four main tracks and thirteen switching tracks; the Santa Fe, with two main tracks and ten switching tracks; the Chicago, Madison & Northern, with two main track; the Chicago & Alton, with one switching track; and the St. Charles Air Line Railroad, having two main tracks owned and used jointly by the Illinois Central, the Michigan Central, the Chicago, Burlington & Quincy, and the Chicago & Northwestern Railroads. In addition to this the C. & W. I. Company's tracks were used by the Wabash, the Monon, the C. & E. I., the Erie and the Grand Trunk Companies; thus, counting the Illinois Central and Chicago, Madison & Northern as one road, the trains and transfers of fifteen different railroads were concentrated in this field of about five acres.

Thus it will be seen that there were fourteen main tracks and forty-two switching tracks and the traffic over them to be taken care of, to say nothing of the two lines of rails of the City Railway Company, which crossed thirteen of these main and switching tracks. It may be proper to note here also, that the records of the different lines show that during the month of March, 1898, five thousand cars and five hundred engines passed this point daily. The plan prepared by the Advisory Board of Engineers of the several railroads and finally adopted, provided that the tracks of the

*Engineer in charge, Joint Track Elevation and Depression Sixteenth and Clark streets



—PLAN OF TRACK ELEVATION AND DEPRESSION TO ELIMINATE THE GRADE CROSSINGS AT 15TH AND 16TH STS., CHICAGO.

Reproduced from the Engineering News.

Fig. 553.

Chicago & Western Indiana and the Sante Fe Companies should be depressed about nine feet, and that all other tracks in this field should be elevated about ten feet. It also provided that Clark street should be elevated and pass over the depressed tracks on a steel viaduct, and that in order to permit its south approach to pass under them the St. Charles Air Line tracks were to be moved south eighty-five feet and pass over Clark street on a steel bridge.

Mr. James Dun, Chief Engineer of the Atchison, Topeka & Santa Fe Railway Company, was chosen by the Advisory Board of Engineers to have general supervision of the work, and on the 14th of April a contract for the masonry was let to the Brownell Improvement Company and work under it was begun on the 24th. Owing to the necessity for keeping the traffic moving it was thought to be extremely difficult, if not impossible, to use derricks in handling stone; and after a careful study of the problem it was decided to use concrete for both the retaining walls and abutments. To this time all of the tracks were in their original position, and the only ground upon which walls were to be built, which was clear of tracks, was that for the retaining wall north of the proposed depressed tracks and west of the tracks of the Lake Shore and Rock Island roads, and even this was crossed by two tracks of the Air Line and two Y tracks of the Lake Shore.

Work was begun on the section of this wall lying between the Rock Island tracks and those of the Air Line; north of this section of wall was a short spur track running parallel with it, and after the excavation for the foundations of this section of about 240 feet were made this track was utilized for the concrete mixer and the cars carrying the cement, sand, and stone for immediate use. When this section of wall was completed, temporary bridges having been placed under the Rock Island and Lake Shore tracks, the excavation for the foundation of the abutment was made and the concrete put in place under these bridges to a height of about seven feet, where it was left awaiting the elevation of the tracks. The same course was pursued at the St. Charles Air Line tracks, and in fact at all of the abutments for the fourteen tracks which were to be elevated. In the meantime work was actively prosecuted in the moving of tracks and in the construction of new ones in order to clear the grounds to be occupied by walls and abutments, and at the same time to provide facilities for keeping the traffic moving. From this time forward this work became a large factor in the item of cost, as in most cases new tracks were constructed before the old ones could be abandoned. In this way short sections of the retaining walls were constructed in such places as could be most readily cleared of tracks, the dominant thought in the minds of those in charge of the work being that traffic must be kept moving.

In this manner all of the retaining walls adjacent to the tracks which were to be depressed were finally completed, and the foot-

Fig. 554. Some of the Tracks and Crossings near Clark St. as seen May 1st, 1898, before elevating. View looking southwest from Clark St.

Fig. 555. Chicago and Western Indiana Tracks May 29th, 1898, before elevating. View from 16th Street looking northwest. Walls and Abutments of Concrete Masonry on the left. Concrete mixer at work on the right.

Fig. 556. Conditition of part of the Work, July 31, 1898. Shows two C. & W. I. Tracks in service before temporary Elevation of Tracks was begun. Beginning of excavation of Subway on the right. Trench excavated for foundation of retaining wall in the foreground. Santa Fe Coach Yard and 18th street Viaduct in the background.

ing course and about four feet of the neat work of each of the abutments were put in place. After the completion of the north retaining wall (which I have already mentioned as the first one constructed) an excavation was made adjacent to it wide enough for one track in the subway, except at the crossing of the tracks of the Lake Shore, Rock Island and Air Line railroads.

It was decided before beginning this work that at some stage in its prosecution all of the tracks which were kept alive for the movement of traffic must be raised to or a little above the established grade of the tracks which were to be finally elevated, and that this raise should be made on sand filling. Before beginning this raise, which involved all of the tracks in the field, and which must necessarily be done before any of the depressed tracks could be put into service, the two most northerly of the Chicago & Western Indiana Company's tracks were abandoned, the most northerly one was taken up, and the second one was used as a base for a line of cribbing to retain the sand filling from one end of the proposed depression to the other. Then the elevation of the tracks was begun and the cribbing was put in as the tracks were raised. This raise was made with sand from the Indiana Sand Hills, and only the fact that it was available made this work possible. Thirteen hundred and fifty cars or 42,500 cubic yards of sand were used. The main tracks raised were:

1 Lake Shore (one abandoned).
2 Rock Island.
1 Air Line (one abandoned).
1 Chicago, Madison & Northern (one abandoned).
2 Chicago & Western Indiana (two abandoned).
1 Santa Fe (one abandoned).

Of these, the Lake Shore, Rock Island, Air Line and Chicago, Madison & Northern tracks were to remain elevated, while the Chicago & Western Indiana and Santa Fe were to be depressed. These tracks being raised to the proper elevation the work of driving piles and constructing bridges was begun and carried forward with two pile drivers and a large force of carpenters until the tracks just mentioned, except the Chicago & Western Indiana, were carried on pile bridges. While these bridges were being constructed a track was laid in the excavation, adjacent to the north retaining wall, from the north end in as far as the Lake Shore tracks, and from the south end as far into the depression as the Air Line tracks, ready to begin excavating under those tracks as soon as the pile bridges were completed.

When these bridges were ready the work of excavation was prosecuted day and night until a continuous track could be laid through under the bridges and entirely through the depression. This track was then used as a loading track, and the excavation was made wide enough for a second track. The second one being laid, the first one was turned over to the Chicago & Western Indiana Company and put in use for its out-bound passenger

Fig. 557. View Looking Southwest Aug. 7, 1898. Tracks of the C. & W. I., Santa Fe, C. M. & N. and Air Line Elevated temporarily on sand filling.

Fig. 558. View Looking Northwest Aug. 7, 1898, Shows the C. & W. I., the Santa Fe and the Air Line tracks in the foreground, and the Lake Shore and Rock Island tracks in the background; the first elevated temporarily and the last named permanently.

business and the freight traffic out and in of the Erie and the Monon. At this stage the two Chicago & Western Indiana tracks which had been elevated were abandoned and taken up, and the passenger business of that road in-bound used the track of the Santa Fe (which still remained elevated), as did also the Grand Trunk and the C. & E. I. Companies for their in and out freight business.

It should be noted here that the temporary elevated Santa Fe track was carried on a pile bridge from the Rock Island tracks to its entrance into the coach yards of that company south of 16th street. This was necessary in order that the excavation for the second track of the Santa Fe alongside of it could be made and that track made ready for service in the depression before abandoning the elevated track. The excavation for the two Chicago & Western Indiana tracks already depressed had been accomplished with ordinary labor, and now for the first time it became possible to use a steam-shovel and one was put in at the north end of the depression, using the second depressed track of the Chicago & Western Indiana Company for a loading track. As the steam-shovel could not work under the pile bridges a force of laborers was now employed to remove the material under each of these, using the same loading track, so that before the steam-shovel reached them a space as wide as the cut taken by the steam-shovel had been cleared under these bridges, and when the steam-shovel reached them the boom was lowered and it was moved through by hand. The boom was then set up and work resumed.

The first cut of the steam-shovel to this point excavated a space only wide enough for one track, leaving the berm and slope necessary to support and safely carry the remaining Santa Fe elevated track, but after passing the Lake Shore and Rock Island tracks the entire width of the material remaining in the subway was taken out with one cut of the shovel, the Santa Fe elevated track at this point being carried on the temporary pile bridge above mentioned. It should be stated here that immediately after passing the Air Line bridge the two Santa Fe depressed tracks diverge from the main subway at an angle of about 15 degrees, and from that point to the Santa Fe coach yard occupy a subway independent of the main subway. This first cut of the shovel then took out all of the material in the main subway south of the Rock Island tracks. In the meantime the shovel brigade had made the excavation for one depressed Santa Fe track (in the Santa Fe independent subway, the other being still carried on the pile trestle, and in this way the Santa Fe was provided with a connection between its coach yard and the main subway.

The Santa Fe elevated track was now abandoned and taken up, its supporting trestle removed, and the steam-shovel was returned to the north end of the main subway and made a final cut as far south as the Lake Shore tracks, taking out the material

Fig 559. Tracks in the Depression Sept. 8, 1898. Temporary bridges of the Lake Shore, Rock Island and Air Line in the foreground. View from 16th Street looking northeast. Excavation of Subway not completed.

which had till now carried the elevated Santa Fe track, thus substantially completing the excavation of the subways. After the excavation of the subways had been made it was found that many of the piles in the temporary bridges carrying the elevated tracks had while being driven encountered buried timber and cross ties, and had thus been deflected from a perpendicular to such an extent that a sufficient clearance was not found for the depressed tracks. Some of these were cut off at the level of the depressed tracks and moved to a perpendicular position, while others were taken out and posts of square timber substituted.

The remaining tracks were now laid in the main subway and

Fig. 560. C. & W. I. and Santa Fe Tracks in the depression Oct. 9, 1898. View from the Lake Shore temporary bridge looking southwest. St. Charles Air Line temporary bridge in the background.

temporary connections made with the freight yards of the Santa Fe, the Grand Trunk, the C. & E. I. and Erie companies on the north, and with the Santa Fe and C. & W. I. coach yards on the south. The final connections of these yards, except the C. & W. I. coach yard, with the tracks in the subways were then made, it being necessary to depress many of these connecting tracks, as well as the C. & W. I. Co's passenger tracks while they were in service.

It is perhaps worthy of mention that the subways were provided with a complete system of drainage through a pump-house built in connection with and made part of the north retaining wall. This is located about midway of the main subway, where a chamber is constructed of concrete having an arched roof. The opening or chamber is fourteen feet long with the tracks, and twelve feet wide inside. This space is divided into two pits or cisterns, separated by a concrete wall two feet thick and five feet high above the floor of the pits, which is on the datum plane. The front wall is brought to the same elevation as the division wall, and on these walls are placed iron girders made of old rails, the ends of which are built into the back wall of the chamber. These girders are designed to carry the floor of the chamber upon which will rest the pumps when finally installed. The walls of the chamber are six feet high to the spring line of the arch, which is semi-circular, with a radius of seven feet. The front pit under this chamber is 5x14 feet and the back one 4 x14 feet, each five feet deep. The main drainage from the subway consists of three cast iron pipes 24 inches in diameter, leading from the river through the back wall of the pump-house, thus giving a free outlet from the smaller of the two pits. Three openings in the middle wall are provided, of the same capacity as the pipes leading to the river. The front wall is provided with four openings, two of 20 inches each and two of 24 inches. These openings were built around forms provided for that purpose as the concrete work was carried up.

Outside of the pump-house along the wall of the subway a concrete catch basin is constructed, and leading from this across the six tracks in the subway are laid two 20-inch cast iron pipes, and across four of the tracks are laid two 24-inch pipes. These pipes are not continuous, but lead through concrete catch basins between each pair of tracks, and into one placed at the east wall. These pipes are all laid on the datum line. Leading from these catch basins, both north and south, there are seven lines of 12-inch cast iron pipes; thus there is one line of this pipe between each two lines of the tracks, and one line along each wall. These pipes are laid with a fall of 1-10 of a foot in each hundred feet, and lead into the catch basins before described. The joints are not cemented, but are laid in such a manner that they will take water freely, and are covered with coarse broken rock. There are about 4,600 lineal feet of 12-inch pipe laid as above.

Fig. 561. Santa Fe tracks as depressed Oct. 9, 1898. View from C. M. & N. temporary bridge looking south, Santa Fe coach yard in the background.

Fig. 562. C. & W. I. and Santa Fe tracks as depressed Oct. 9, 1898. View from the Lake Shore temporary bridge looking northwest. Tracks leading to the freight yards of the Santa Fe, the C. & E. I., the Grand Trunk, the Wabash, the Erie and the Monon, and the main tracks to Dearborn Station in the background.

The top of the rail of the lowest track in the depression is 3 feet above datum, so that until the water in the river rises 2½ feet the drainage will be taken care of by gravity. If the river should rise so high as to threaten to obstruct traffic, then recourse must be had to the pumps, for which provision has been made in

the pump-house above described. The middle wall in the pump-house, it will be remembered, is provided with three 24-inch openings. These openings are provided with valves which in case of an extraordinary high stage of water in the river can be closed, and by pumping from the front pit over this division wall to the back one the subway can soon be drained. It is now proposed to install in this pump-house pumps of a capacity of about 4,500 gallons per minute, with which it is believed the storm water can be successfully controlled, while the valves in the middle wall keep back the river water.

In conclusion it may be stated that nothing more has been attempted in this paper than to give the reader a passing view of the work in its different stages, showing also some of the complex conditions attending the carrying out of the plans agreed upon by the engineers of the several companies interested, and the hope may be expressed here that this has been in some small measure accomplished.

LX.

TRACK ELEVATION OF THE LAKE SHORE & MICHIGAN SOUTHERN RY. AND THE CHICAGO, ROCK SLAND & PACIFIC RY.

By Marvin H. Dey, C. E.*

An ordinance requiring the Lake Shore & Michigan Southern Railway Company and the Chicago, Rock Island & Pacific Railway Company to elevate the plane of certain of their tracks within the city of Chicago, was passed by the City Council July 9, 1894, and was accepted by the railway companies during the same month.

This ordinance provided for raising the joint tracks from Sixteenth street to Sixty-third street, and from thence over State street on the Lake Shore, and over Sixty-ninth street on the Rock Island. It provided for the abolition of forty-five street grade crossings, including fifteen street-railway crossings, and indirectly for two railroad crossings. The ordnance provided that the railways should not only elevate their tracks but that they should construct the subways under them, paving the floors with brick, laying cement walks, and restoring the pavement, curbs and walks on the approaches. Twelve feet clear head room was required, except where the streets were occupied by street railways, in which case a thirteen and one-half foot clearance was required. The entire width of streets was to be bridged, either with a clear span or with supports at the curb line. The work was to be commenced within thirty days from the filing of the acceptance of the ordinance and to be completed by August 1, 1899. The city assumed all land damages caused by the elevation of the tracks.

From the north end of the north approach, to the elevation to the south end of the south approach is a distance of a little less than seven miles. In that distance there are two under railway crossings and thirty-nine subways at streets and one private under crossing. About sixty-two miles of single track have been elevated and all streets within the limits of this elevation have been carried under the railways.

As the right of way of the Lake Shore & Rock Island from Chicago to Englewood is owned jointly by the two roads, it was decided to organize an independent track elevation department that would not be too closely identified with either road. Mr. L. H. Clarke was put in charge of this department with the title of Engineer of Track Elevation, and to him was assigned the task

* Asst. Engineer, Track Elevation L.S.&M.S., and C. R. I. & P. Rys.

of elevating the joint tracks and distributing the expenditure between the two roads.

The care of the tracks and all work that directly affected them have been done by company men. This includes raising tracks, unloading and handling the sand filling, building the abutment masonry, the construction of the temporary bridges and part of the retaining walls.

The work on steel bridges, concrete and subways was all done by contract.

The abutment masonry stone was cut and numbered for laying at the quarries. All stone was rock faced, cut to $\frac{3}{8}$ in. joints and ranged in thickness from 14 to 24 inches. The backing was composed of the same class of stone as the face. Part of the first class stone came from North Amherst, Ohio, and part from Lamont quarries. The rubble stone came largely from the Joliet region. The masonry was laid with Louisville or Utica cement and joints scraped and pointed with Portland.

The filling was composed of sand brought from Dune Park, a station on the Lake Shore road about thirty miles from the work. It was contracted for on board cars at the pit. The sand was unloaded with plows, cable and "spool car" supplied with steam from the locomotive.

The bridges were contracted for erected in place.

The following tables will show statistically the progress and extent of the work.

TABLE I.

YEAR.	Tracks Elevated from—	Subways Provided.	Length of Elevation.	Length of single Track Elevated.	Bridges Erected.	Tracks on Bridges.	Steel in Bridges.	Abutment Masonry Exclusive of Concrete Foundations.	Rubble Masonry.	Concrete foundations.	Subway excavations.	Pavement.	Sand.
		No	Miles	Miles	No.	No.	Tons.	Cu. Yds.	Cu. Yds.	Cu. Yds.	Cu. Yds.	Sq. Yds.	Cu. Yds.
1894	Archer to 23rd	3	0.3	1.4	3	14	700	2,400	5,200	2,800	7,700	3,700	58,500
1895	23rd to 38th	12	1.8	7.6	12	50	2,500	6,400	600	3,800	30,800	17,700	220,700
1896	47th to 59th	7	1.5	13.5	7	49	3,050	4,400	13,600	11,400	28,800	15,100	313,600
1897	38th to 47th	6	1.1	13 6	7	59	2,860	5,900	4,600	5,200	27,400	10,400	239,000
1898	16th to Archer 59th to 69th 61st to State Approaches	11	2.5	25.9	15	116	7,000	17,000	5,000	7,000	50,000	20,000	655,700
Total..................		39	7.2	62 0	44	238	16 110	36,100	29,000	30,200	144,700	66,900	1,487,500

The totals show 39 subways, 7.2 miles of right of way elevated and 62 miles of track, which makes 288 crossings of streets on 44 independent bridges.

The largest items of material used are 16,000 tons of steel in

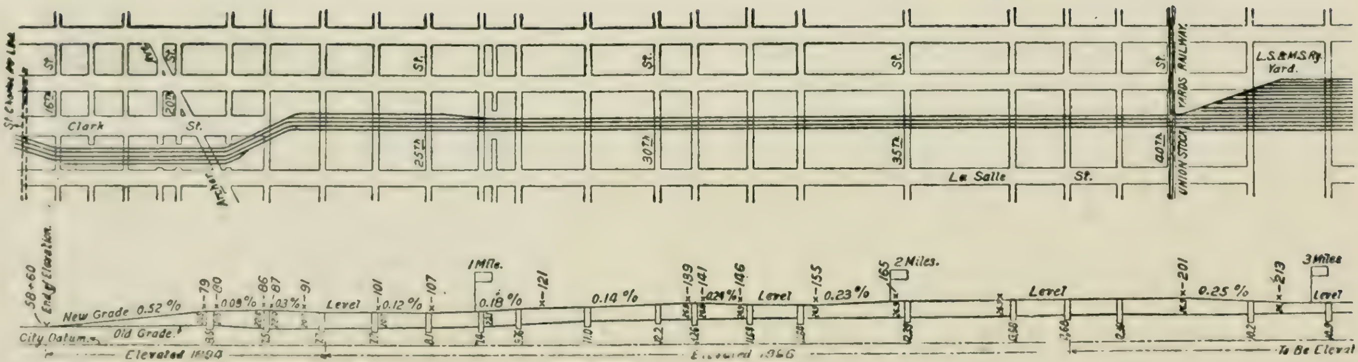


Fig. 563. Plat and Profile of the L. S. & M. S. and C. R. I. & P. Railways from 16th to 44th Streets.

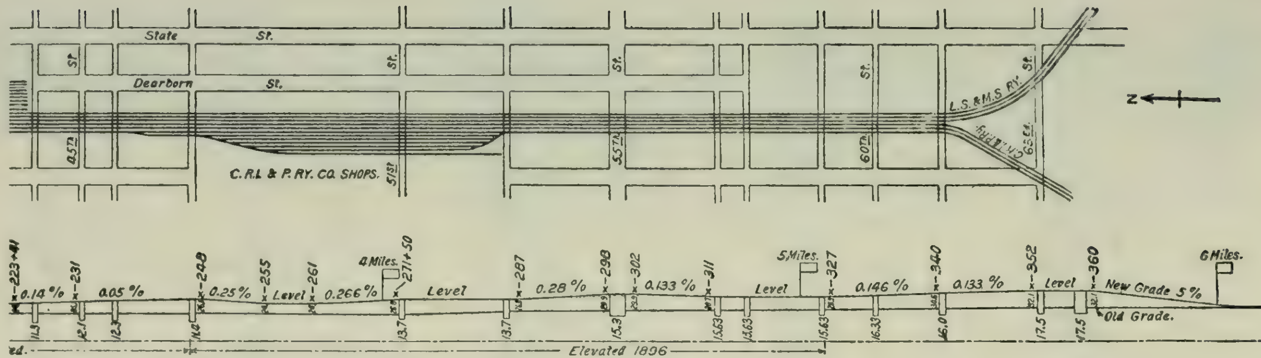


Fig. 564. Plat and Profile of the L. S. & M. S. and C., R. I. & P. Railways from 44th Street to Englewood.

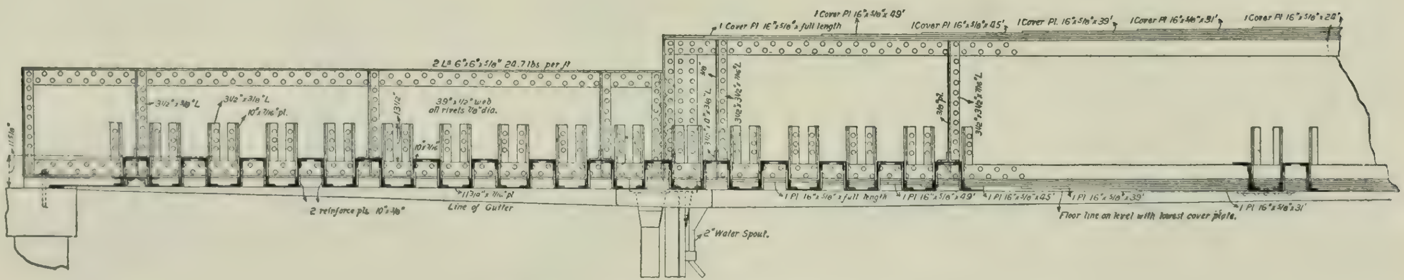


Fig. 565. Details of Archer Ave. Bridge.

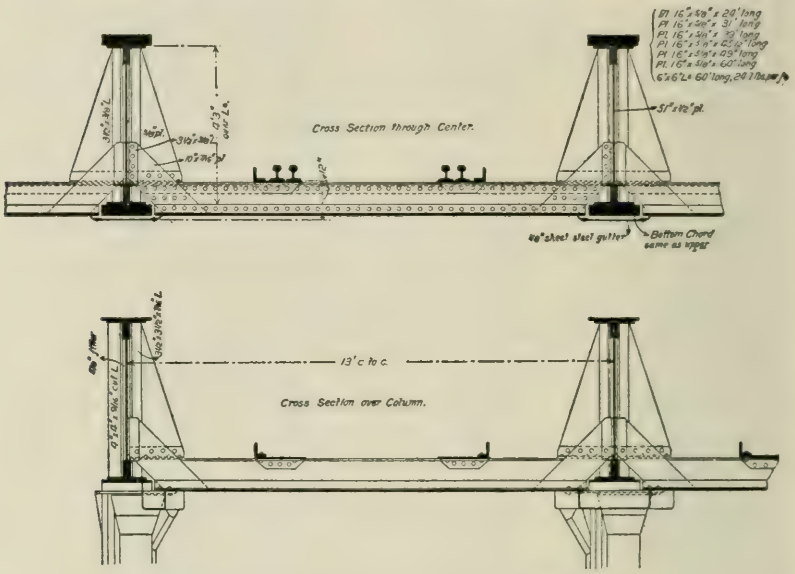


Fig. 566. Details of Archer Ave. Bridge.

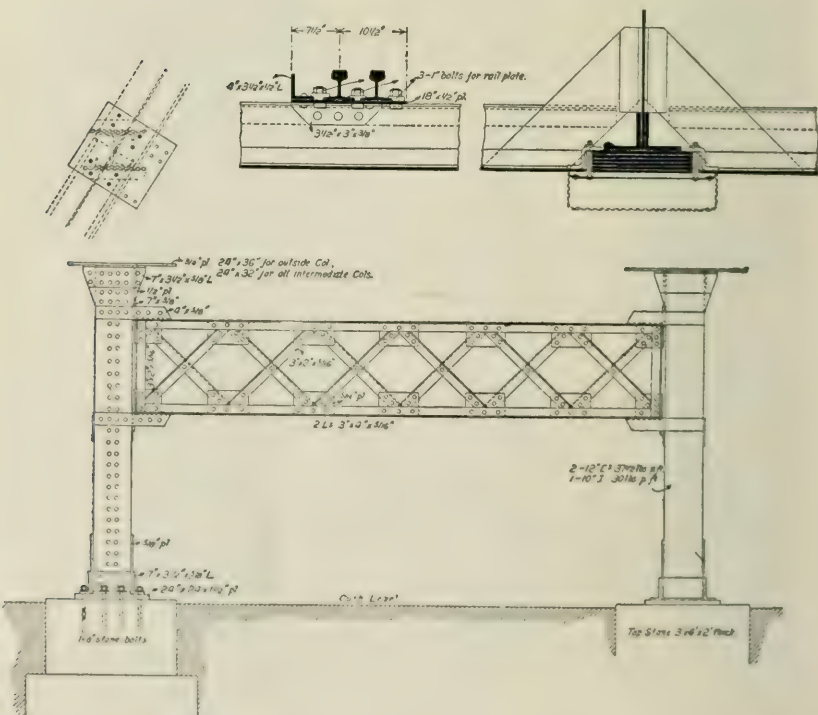


Fig. 567. Details of Archer Ave. Bridge.

bridges, 36,000 cubic yards of abutment masonry, 29,000 cubic yards of rubble, 30,000 cubic yards of concrete, 145,000 cubic yards of subway excavation, 67,000 square yards of pavement and 1,487,500 cubic yards of sand filling.

Figs. 563 and 564 show roughly the location and profile of the joint right-of-way of the L. S. & M. S. and C. R. I. & P. Railways between 16th and 63rd streets. They give but a very imperfect idea of the arrangement or extent of the yards that have been elevated. The Rock Island 43rd street and the Lake Shore 18th street and Englewood yards are not shown at all.

Figs. 565, 566 and 567 represent parts of the Archer avenue bridge and show the type of bridge used during the season of 1894. The floor was built up of plates and angles into a continuous corrugated or troughed surface suspended directly from the web of the girder by hangers. The rails were attached by bolts and clips to rail plates resting directly on the upper surface of the troughs. The gutters shown in the plan have been abandoned on account of difficulty in keeping them in serviceable condition. From the bottom of bridge to the base of rail was 12 in. The bridges built in 1894 had supports at the curb lines.

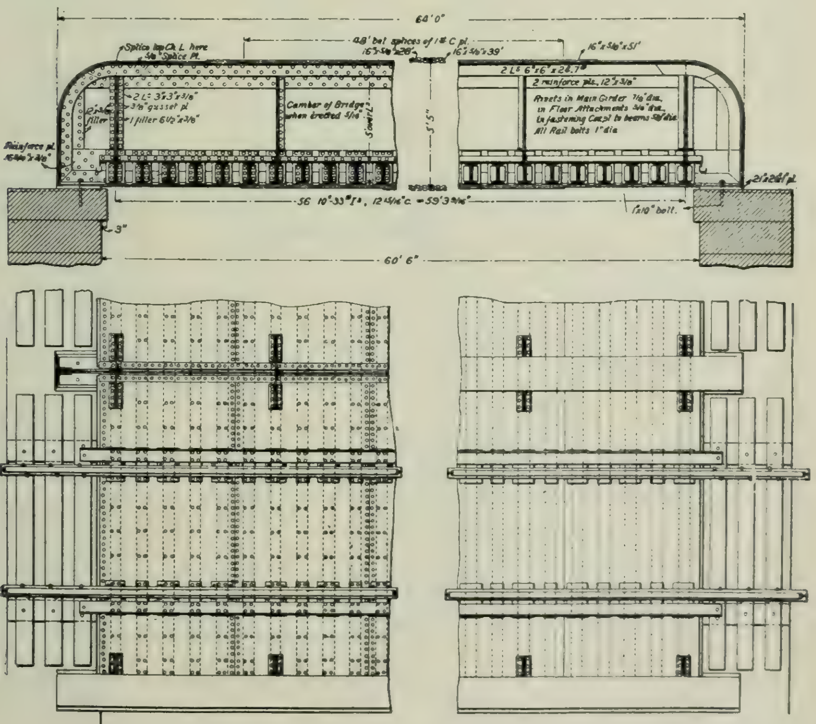


Fig. 568. Standard 60 ft. Bridge.

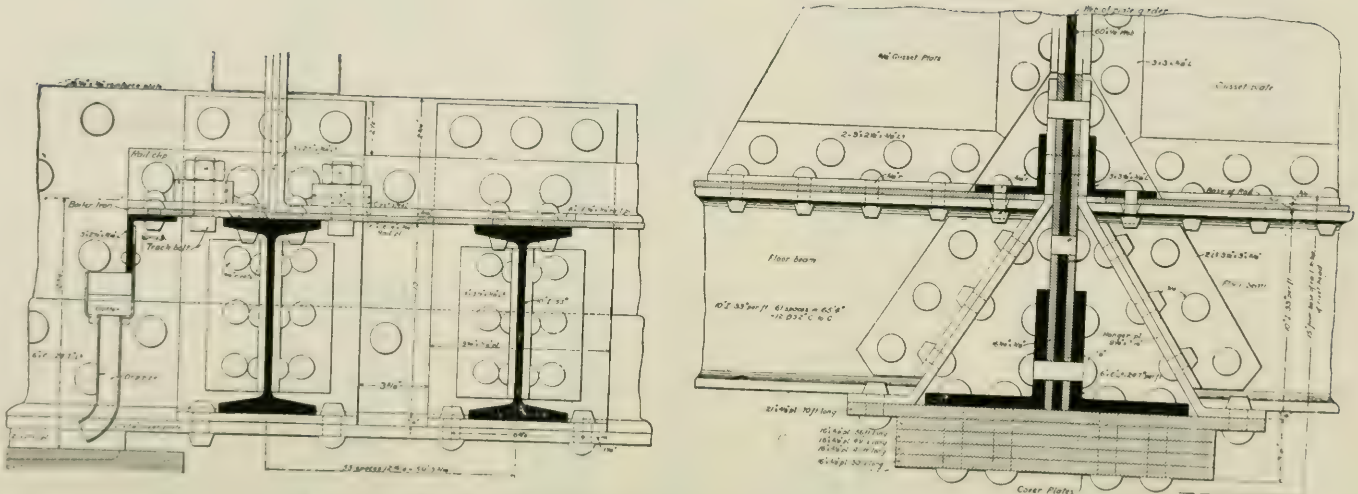


Fig. 569. Detail showing the Connection of I Beams with Girders, 1895.

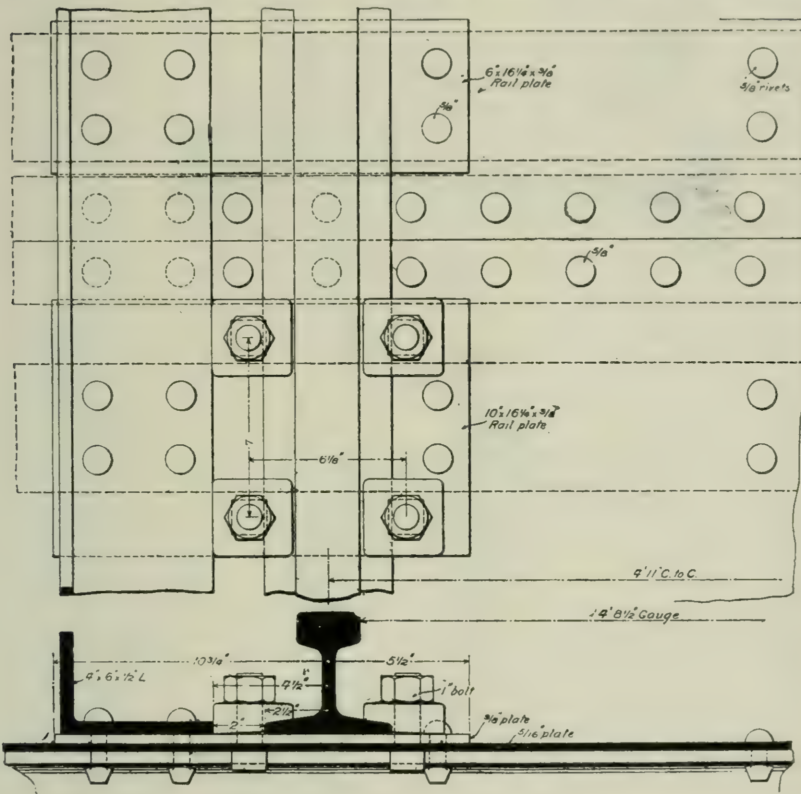


Fig. 570. Detail of Rail Fastening and Guard Angle.

Figs. 568, 569 and 570 are taken from the 1895 standard bridge plans, which, with only minor modification, are still in use.

A single span reaches from abutment to abutment without intermediate supports. The girders are but 5 ft. in height so that their top chords do not reach above the top of an ordinary flat car. The girders are placed generally 13 ft. center to center, which gives a clear space between top chords of 11 ft. 4 in. The floor is composed of 10 in. "I" beams supported by hangers riveted directly to the web of the girder and attached to the top plate of the lower chord as shown in Fig. 569. This connection of the beams to the girders is perhaps the most distinctive feature of the bridge. A tight $\frac{5}{16}$ in. floor plate rests on the beams. The rail bears directly on $\frac{3}{8}$ in. rail plates over the beams and is held in place by clips and bolts, as shown in Fig. 570. Continuous 4 in. x 6 in. angles are riveted outside of the rails to act as guards. The distance from base of rail to bottom of girder is 15 in.

Fig. 571 shows the details of floor used since 1895. By using a

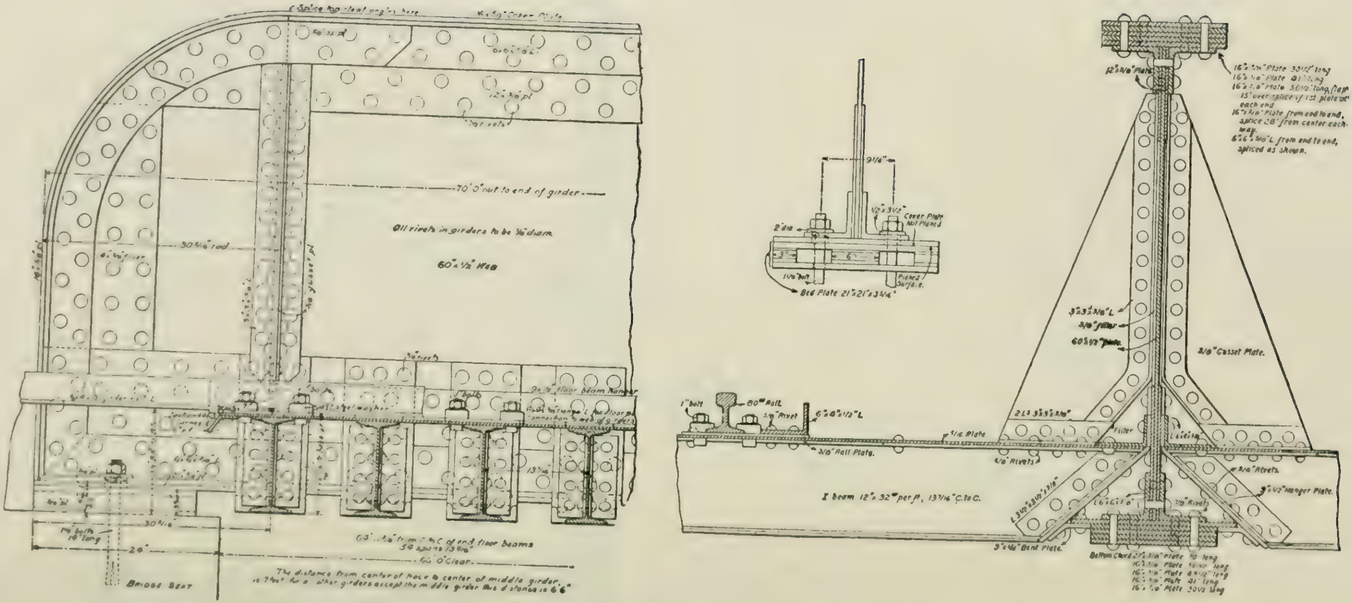


Fig. 571. Details Standard Bridge showing I Beam Connection, 1896.

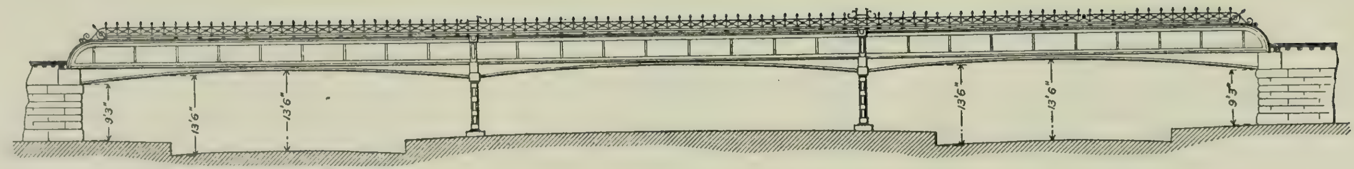


Fig. 572. Elevation of Garfield Boulevard Bridge.

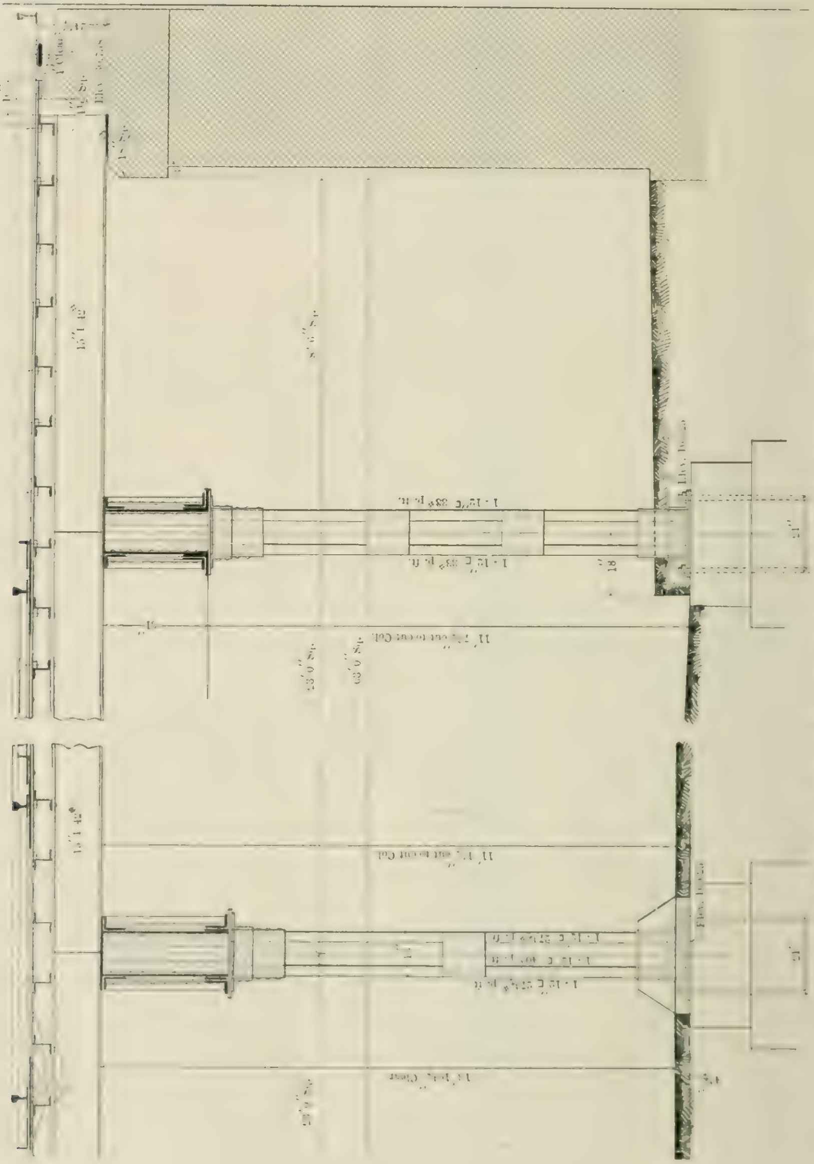


Fig. 573. Details of Deck Bridge 61st-63d and State Streets.

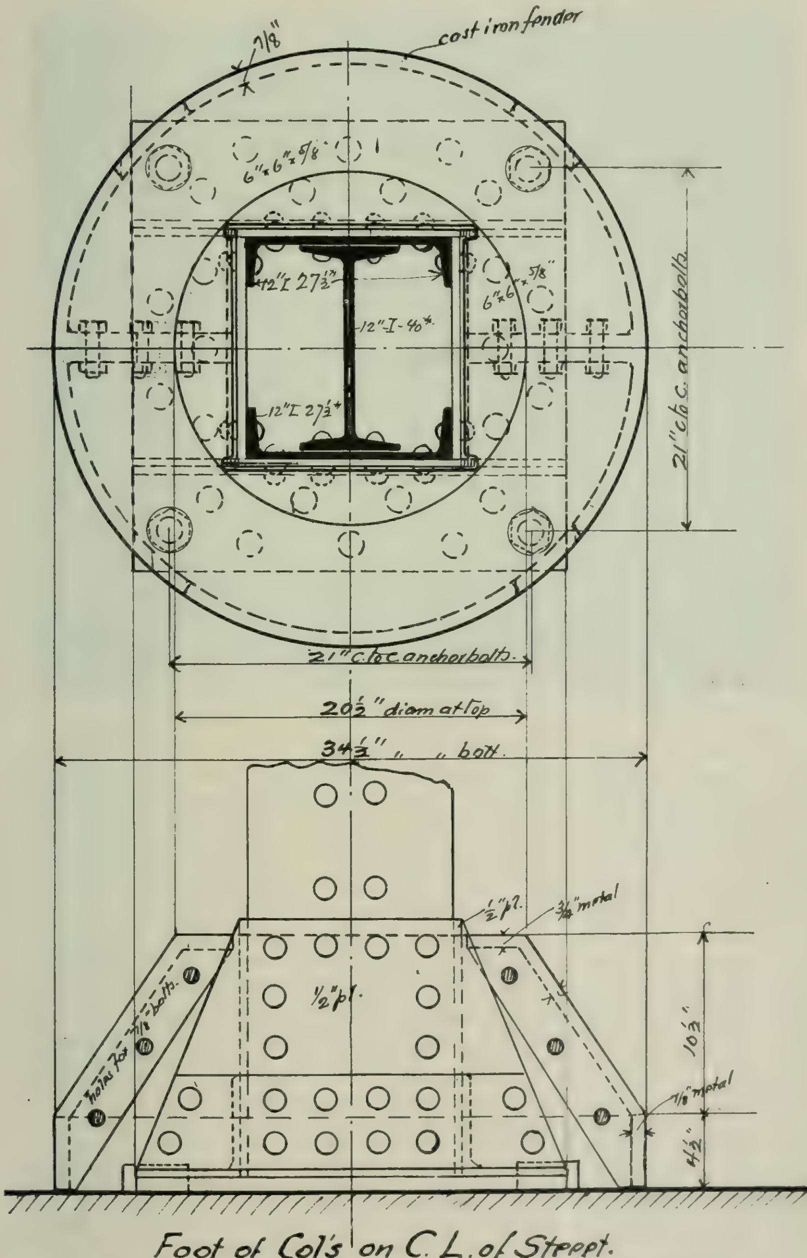


Fig. 574. Details of Foot of Center Column of Deck Bridges.

Fig. 575. State Street Subway while Work on Bridge is Progressing.

12 in. beam and hanging it so that the bottom of the beam is even with the bottom of the girder, a stiffer and thinner floor is obtained without increase in the amount of metal used. An elevation of the Garfield Boulevard bridge is shown in Fig. 572. It is essentially three standard spans with cresting and false arches to relieve the severe plainness of the unornamented structure.

At 61st, 63rd and State streets, which are crossed by the many tracks of the Lake Shore Englewood yard, an entirely different type of bride is used. The girder type was abandoned an account of its obstruction of the spaces between cars used by switchmen, the danger to trainmen and the impossibility of putting in switches or cross-overs within the limits of the bridge. A deck bridge was adopted supported by lines of posts at the curbs and at the centers of the streets. On these posts are longitudinal box girders which support the ends of 15 in. "I" beams. Centering on the tracks, and at right angles to the "I" beams, are 4 in. "Z" bars that act as ties distributing the load on the rail to the adjoining "I" beams. The whole is covered by a floor plate on which are the rail plates and guard angles and to which the rail is fastened by clips and bolts.

To allow for expansion and contraction these bridges are

Fig. 576. 63d. Street Subway, Showing Bridge and Masonry.

built in panels of six tracks each, which are connected with each other by plates loosely bolted through slotted holes.

Fig. 573 gives the characteristic features of the deck bridges. Fig. 575 presents a view of the State street subway at the time the work on the bridge was in progress. Fig. 576 shows bridge and masonry work on 63d street subway. Figs. 577 and 578 show the arrangement and number of tracks crossing 63rd and State street.

These two streets forming, as they do, a continuous subway nearly two thousand feet in length, and crossed by sixty-four tracks, constitute, I believe, by far the most extensive and most expensive subway yet constructed in Chicago.

Discussion of Track Elevation in Chicago--November 16, 1898.

Mr. E. H. Lee:* I wish to bring up a couple of questions that have occurred to me and which I am sure the gentlemen here present could discuss very entertainingly to the society. In the first place

*E. H. Lee, Principal Assistant Engineer, Joint Elevation of Tracks, 16th and Clark streets.

I notice that some of the engineers have used concrete, and they not only have adopted it for their retaining walls, but also have used it for abutments and for coping. All their masonry work has been composed of that material. On the other hand I note by observation that some here use rubble masonry for retaining walls. I should be glad to learn the reason for the use of concrete; whether the reason or reasons are entirely from motives of economy or whether there is some other motive behind it. Another question which has occurred to me is as to the relative economy and the relative value from an engineering standpoint of the different girder floors that have been adopted. Various devices have been used, but broadly the two distinguishing features seem to be the I-beam floor covered by flat plates, with some such protection as asphaltum or tar and the trough or buckle plate floor carrying ballast and ties. I think it would be especially valuable to the society to have the relative cost of these floors and their relative advantages.

One thing some of us have learned, is the elasticity of gradient and alignment which may be used. The topography of the country here is of such a nature that engineers have not been called upon to go to extremes in these respects. Perhaps track elevation has developed a few extreme examples of stiff curvature and grades. For instance, I know of curves as high as 22 degrees that have been used successfully day after day with all kinds of traffic, and I know of at least one crossing grade that was used for a time successfully with as high as a 7% grade and a 15 degree curve on it. If some of our members would give us the details of difficulties that have been met, it might lead to an interesting discussion, and lead other engineers besides themselves to appreciate some of the difficulties which have been met in dealing with track elevation here.

Mr. L. H. Evans (C. & N. W.): Mr. President, I can start that, I think, by giving a few of the reasons for using dimension stone for the abutments, and concrete for the foundations on the Northwestern work. At the present time we are completing, or have nearly finished all the preliminary work for the track to be elevated next spring, part of which is about five miles of retaining wall. We have been able to put in concrete cheaper than rubble; it is an entirely different class of labor, so we have made the foundation for the retaining wall, which is practically the same area as the rubble wall above it, of concrete. That allows us to work one set of men who are common laborers entirely at that class of work, and the masons, high-priced labor, fill out with the rubble. In that way we were able to advance the work very rapidly, completing as much as four hundred feet of wall a day. The area of the wall would be close to a cubic yard of concrete in the foundation and a cubic yard of rubble above the foundation. I think, too, that the concrete footings will last better than Lemont rubble would at the ground line.

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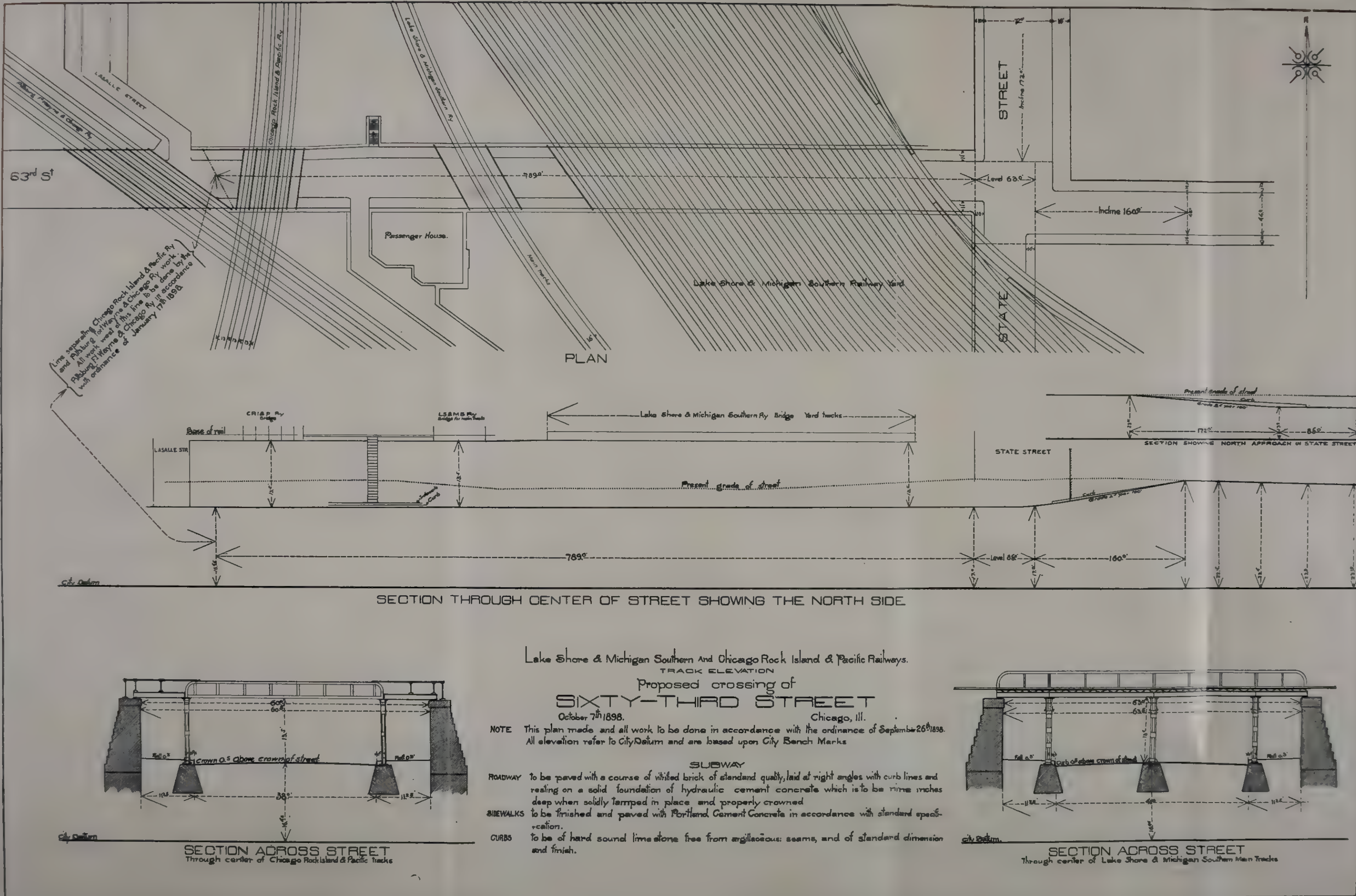
FIG. 577. DEY TRACK ELEVATION - L. S. & M. S. AND C., R. I. & P. RYS.



Lake Shore & Michigan Southern And Chicago Rock Island & Pacific Railways.

TRACK ELEVATION

Proposed crossing of

SIXTY-THIRD STREET

October 7th 1898. Chicago, Ill.

NOTE This plan made and all work to be done in accordance with the ordinance of September 26th 1898. All elevation refer to City Datum and are based upon City Bench Marks.

SUBWAY

ROADWAY to be paved with a course of vitrified brick of standard quality, laid at right angles with curb lines and resting on a solid foundation of hydraulic cement concrete which is to be nine inches deep when solidly tamped in place and properly crowned.

SIDEWALKS to be finished and paved with Portland Cement Concrete in accordance with standard specification.

CURBS to be of hard sound lime stone free from argillaceous seams, and of standard dimension and finish.

In the abutments that we built we put in a foundation of concrete, and on top of that dimension stone for the facing stone, and backed it up with Lemont rubble, because we have a quarry of very good limestone that we have used on the road for over forty years with good results, and we are not at all afraid of it, and in fact preferred this stone to that from any other quarry that we know of.

I think that the abutment as we build it, concrete for the foundation, dimension stone for the face, and Lemont stone rubble backing, is cheaper than first-class concrete work would be, and quite a little cheaper. Also, to my mind, it looks better. That may be due to a prejudice or lack of experience in concrete work, but to me a first-class dimension stone abutment looks better than any concrete abutment that I ever saw.

The bridge floor problem I think is quite an extensive one; we have a good many high grade bridge men here; I think they ought to chip in a little on that. It is out of the line of regular elevation. It is something they figure on more or less, and I believe they ought to help out on that discussion.

Mr. Lee: Do I understand Mr. Evans to say that his company owns this quarry?

Mr. Evans: Yes, and we cut the stone at the quarry.

Mr. Lee: Operate it yourselves?

Mr. Evans: Yes, entirely.

The Chairman: I heard only a part of the original papers, so that I am not familiar with the parties who used the concrete abutments or retaining walls. I know that they used them down at the 16th street crossing. Perhaps Mr. Lee can give us some of the reasons why it was adopted at that particular place, in answer to his own question.

Mr. Lee: Mr. Chairman, the parties that I had in mind especially were the St. Paul people. They have adopted concrete, and have put it in everywhere. I am free to say that I am, to a certain extent, on their side of the house, so far as concrete is concerned, except where there are special advantages, such as Mr. Evans describes, in the use of dimension stone facing and rubble backing.

In reply to the suggestion that the reasons be given why concrete was used at 16th street, I would say that as near as I know, it is the judgment of both the Supervising Engineer and the Engineer in charge of that work that first-class concrete is a thoroughly satisfactory material both for abutment and retaining wall use. In this particular case it was entirely out of the question to consider the handling of dimension stone. It was a matter of impossibility to put up the rigging that would have been necessary to handle dimension stone. We were very frequently forced to put in a wall in a circumscribed location, where, for instance, there might be a traffic track on each side so close that we had barely room to put in forms for the concrete. In many cases

concrete had to be wheeled perhaps 150 feet, there being not even opportunity to have adjacent standing room for the mixer; so that it would have been impossible to locate a derrick car near enough to handle the material. This reduced the question to a matter of either building the wall of "two-hand stone" or of concrete. The use of the latter, I believe, was considered far preferable to using small rubble work, or small dimension stone.

We have had one or two good tests, if I might call them such, of the strength of the work we have put in down there. For instance, we have not been able to keep the work going night and day, as Mr. Rogers has stated that they did on their work. We made no further provisions for bonding between the different courses than to thoroughly clean off and wet that which was already in; so that in nearly every case the concrete had set in the previous course before the one following it was put on. This was especially true in regard to the coping. We had occasion to do some of our excavating with a steam shovel. The coping is only fifteen inches thick, with a projection of four inches. The shovel engineer in one case, through carelessness, got his dipper too close under that four-inch projection, with the result that he broke down his machine, taking off from the under side of the projection a chip no larger than a six-inch cube.

In another case we had a little grief in the way of running a car off the end of a track on to what was perhaps the thinnest sectioned wall which we built. The car had a drop of about six feet. It was loaded with stone, and came down on the wall hard enough to smash the car to a very considerable extent, but it made absolutely no impression on the wall.

We think that these tests show concrete is a very good material in a general way, and that we have a good article of concrete in that particular place. Of course concrete is like some other things: "When it is good it is very, very good, and when it is bad it is awful."

In the use of concrete, the gist of the whole situation would seem to be adequate inspection of cement and proper supervision when the material goes in. If these two things are secured the results, as in our case, are satisfactory.

Mr. W. W. Curtis: What was the age of those concrete walls you referred to?

Mr. Lee: The concrete had been in the wall for perhaps two months.

Mr. W. A. Rogers (C. M. & S. P. R.): The reasons which decided the use of concrete by the Chicago, Milwaukee & St. Paul Railway were several. In the first place, the concrete could be put in with greater facility than the heavy bridge stone. In the second place, we considered that it would be just as durable as any stone that we could get in this part of the country, and perhaps considerably more so than the Joliet stone. That is, we believed that the concrete would be durable. In the third place, we believed that we could build a

better looking abutment for the same money, of concrete, than we could of stone masonry. In the fourth place, from our experience we knew that we could build a concrete abutment considerably cheaper than we could build what we call "a bridge stone abutment," and we have no reason yet to change our opinion.

Mr. Evans: I do not believe the Milwaukee road built their concrete abutments any quicker than we did our dimension stone abutments. We made 117 cubic yards of stone a day, for the working days of the month; for three months we made that average. We did better than that some days. From the amount of work they have done this year, and from the time they started and finished, I am satisfied they did not make any such average record.

Mr. Lee: How many gangs did you use?

Mr. Evans: One gang laying stone.

I stated in my paper we averaged in three and a half days two abutments. I think they worked about eight masons. One advantage about this work was that the men could set a row of faced dimension stone on one abutment at one side, and then go on to the other side and set another course of stone, and the side that they had left would be backed up by different men entirely, so that they would be ready for them after they had laid the course on the other side of the street. It certainly gave a good chance to work. I know that was the record, 117 yards a day. We made one subway in three days and a half, and I want to ask Mr. Rogers if they built two concrete abutments in three days and a half?

Mr. Rogers: I could not say as to that, but I can say that we made no effort at speed, but when we were working our concrete force we averaged about 140 yards in 24 hours, working night and day.

Mr. Evans: That is two days.

Mr. Rogers: Yes.

Mr. Evans: That is just about half.

Mr. Rogers: I want to emphasize the fact that we made no particular effort at speed. We could have done more if we had wished to.

Mr. G. H. Bremner (C. B & Q.): Mr. Chairman, our road will use masonry abutments, made out of Monon Indiana limestone. They chose this not for its economy over concrete, but because of its permanency. Nearly all of our masonry work, wherever it has been put in, has been put in with a view of as long use as possible without any renewal, and we think that this stone will last forever, while the question of using concrete is still more or less an experiment. As to the appearance of the wall, we think that the masonry will probably be better appearing than the concrete, but I do not think that had very much to do with making the decision. As to the amount of masonry laid in a day; this summer we laid about forty to sixty yards a day with one gang

of five masons and our derrick car. We had no unloading of stone. We merely handled it once, from the car into the wall. In laying our concrete foundations we probably put in in the neighborhood of 120 yards, and sometimes more in a day. Of course that was cheap concrete and was handled rapidly. I might add, we have a very good class of concrete in the foundation.

There was another point that Mr. Lee brought up in the first part of his talk. That was in relation to the curves in Chicago. He spoke of a 22-degree curve. I think it is nothing uncommon in Chicago, outside of track elevation work, for curves to be much sharper than that. I know we use curves with a radius of about 225 feet very commonly, and we have one curve with a radius of a hundred feet.

Mr. Lee: You do not run your passenger trains around those curves, do you?

Mr. Bremner: No, we could not run them around a 225-foot radius. We do not make a practice of putting them in unless we have to.

Mr. Roberts: I would like to inquire the relative cost per cubic yard of the masonry and the concrete.

The Chairman: Is any gentleman prepared with a statement of cost?

Mr. Evans: It would be hardly right to give the cost of our work as we own the quarry. We are not in the market competing with the men that sell stone, so we ought not to say anything about its cost.

Mr. Rogers: I will say that our concrete work, that is, concrete above the footings, cost us, with freight added on all materials, and the cost of loading gravel which we used, and all the expenses incident to the work which a contractor would have to meet if he were doing the work, on an average, $4.90 a cubic yard. That includes the cost of forms and all material and labor. I would like to ask Mr. Lee if they have the cost of the 16th street work.

Mr. Lee: I would say in reply to Mr. Rogers' question, that I do not feel at liberty to say just what the concrete did cost at 16th street. I am free to say this, however, we cannot make quite as good a showing as he made, for two reasons, perhaps; one being that we had no gravel to load ourselves, and were compelled to buy torpedo sand and crushed stone; and another being that the circumstances which governed the putting in of the concrete were of such a nature that it would be unfair to compare our work with the general track elevation here, where the mixer generally stood alongside the structure into which the concrete went, with little inconvenience from the running of trains. At 16th street crossing I have been told that from an actual count there are from 1,000 to 1,800 train and engine movements a day, perhaps ten thousand cars moving by in twenty four hours. Very frequently

the mixer would stand on one side of a system of tracks, the concrete going in at the other side. I have seen the gang wait for fifteen minutes, being absolutely idle, while traffic was passing on these tracks. Again the proximity of traffic to the structures delayed the work. Again, too, the temporary bridges necessary to carry traffic over the concrete structures frequently made necessary that the work be done in a very confined space. For instance, in finishing up abutments we had, perhaps, six inches of head room between the bottom of the stringer and the top of the abutment, and it was a matter of considerable difficulty to get the material tamped and the job finished in such a confined space, especially when it was the tightest kind of a position for a man to get into on either side of the work. Sometimes we put in from 125 to 150 yards a day, and at other times half that. It depended largely on the accessibility of the walls on which we were working, and also on the facility with which we could get our switching done. Taking it all together, with the various causes of delay, etc., comparison with the work of other roads, would perhaps be, as I said before, unfair.

Mr. T. L. Condron: One of the most striking differences which has been observed is in the falsework that has been used by the different companies. In one case four piles have been called upon to do the same duty that in other cases has been done by a great deal of timber falsework. The question of relative cost and relative advantages I do not think has been clearly brought out in the papers as read. One of the gentlemen, who is not here tonight, said that their road did not consider the four piles safe, but I think we do not have any record of any of Mr. Evans' "four piles" failing. I would like to hear on that point. Also, why the Milwaukee & St. Paul found it necessary to use such elaborate falsework.

Mr. Evans: I will state that the four piles that we put the end of the bridge on were the least that should be there. It was a very easy matter, if the piles settled, and they did settle some, almost as a rule, to put in a post to help out a pair of weak piles, if necessary, at very small expense. It was not at all in the way, and practically cut no figure in the cost of the work. Of course we had to watch the bridges very carefully, and if we saw that there was any settlement we guarded against its continuing, and we were able to hold the bridges up very near to grade. Some of them did settle as much as six inches, but the bank settled with them, so that it did not cut much figure. It certainly is a great saving in the first cost to put them on piles, as we did, and further than that, it expedites the work, which I consider a very essential item. I do not know whether it is looked on that way by those interested, but I know that any delay in the work that can be avoided means money to the railroad interests. If we can do a piece of work in three months, instead of nine months, it seems to me there is a great pecuniary saving in doing it. I think,

too, that the force employed works to better advantage, if everything goes on rapidly, and the day's work shows. You can get better returns from your men.

Mr. Bremner: Did you use more than four piles in any case?

Mr. Evans: On the Rockwell street line we used four piles at each end of the bridge, that is, there would be eight piles to support the bridge, and then, as the work progressed, there would be an intermediate floor resting on that, so that the eight piles would support a bridge and a half. Then there would be two piles at the back wall, besides, that helped to retain the bank of sand filling as well as carry the train on the bridge. In the work that we did this spring we did not use any piles at all. It happened that all of the streets were on the skew, and posts at the curb line, in every case except one, so we placed the bridges right on the iron posts; we permanently placed them, as we brought them from the bridge derrick, and of course there was no settlement there, and very little trouble to maintain the ends. They acted as cantilevers. The first of these bridges that we went over we were more or less worried about the posts that we had to put under this overhanging end, for fear that it would be called upon to do more than it could do. We could not quite tell what the force would be, or what the pressure would be, but we discovered that instead of the post being crushed that we had to nail it up to the back wall to keep it from tipping over. It was a surprise to all of us .The bridge acted as a cantilever.

Mr.W.L.Webb: I will say in regard to the Chicago, Milwaukee & St.Paul work that we began work late in the spring and it was necessary for us to have a bridge that would be thoroughly safe and reliable and the system of falsework which we used was found to be perfectly safe, without any question. Its use and cheapness has recommended it to us and we are going to use it another year from choice. We were forced to use a strong falsework because the banks would be made before we could get the iron bridges. We started the sand work at the time we were given permission to go ahead with the elevation. Considerable time was required for the planning and construction of the iron bridges and the banks were completed before they were received.

Mr. Evans: I want to say in regard to safety, that in putting in the twenty-five subways that we put in this spring, three tracks at every street, and two extra ones, seventy-seven tracks in all, that we had just one car off the track at a bridge, and that was one of our working train cars, with at least two loads of stone on the car, and it was almost the first car over this bridge and over this track, but as there was only one derailment, so far as this year's work is concerned, it was certainly safe.

Mr. Rogers: Mr. Chairman, in addition to what Mr. Webb has said, I wish to say that the Chicago, Milwaukee & St. Paul piles were largely second-hand piles, and their cost was merely the cost of loading and unloading, and that the material is all of

standard sizes, the posts are cut to standard length, and doweled to the caps, the brace planks are all bolted, instead of fastened with spikes, and that this material will be used over and over again, as long as the Chicago, Milwaukee & St. Paul Railway continue their track elevation. Also, the system of falsework that is adopted by us permits the keeping of all of the tracks in service at all times where it is desirable to do so.

Mr. H. P. Boardman: One thing occurs to me, that there are no two parallel cases in this track elevation business; there are no two roads that have exactly or even approximately the same conditions to deal with.

The Chairman: In connection with the raising of the tracks I have observed still another matter, and that is, simply dumping sand in and passing the track right across the street. Mr. Lee, I think, can tell us something of that, and how falsework would have answered at 16th street.

Mr. Lee: Mr. Chairman, the remarks that Mr. Boardman has just made may give, perhaps, a sufficient reason for our method of work. Of course, our problem was different from that of any other track elevation, with, perhaps, one exception, from the fact that we were raising tracks that came together at almost every angle, and that it was necessary to maintain traffic on all of these tracks in all directions at all times. I have understood from Major Vaughn, the engineer in charge, that this question of the raising of the tracks was the subject of a great deal of anxious study on the part of those concerned. Several plans were suggested. I think that to him belongs the credit of solving it in a very elegant manner. We first elevated all the tracks from the original grade to something like a foot or a foot and a half above their final grade. When this elevation was secured by the use of sand filling, we drove piles through this sand filling and put on a deck. We were then in shape to remove the sand filling and to put in the depressed tracks one at a time, without disturbing the traffic on those overhead. The question of why that method was used has occurred to a great many people that have come to 16th street. In fact, it has been a source of amusement to notice how the question has occurred to some of the different men that have come there. I remember in one case the foreman of a pile-driver crew came on to the ground and looked the situation over, and after scratching his head, said, "Well, they ought to have driven those piles before the sand was put in." After looking at the situation a little longer, he said, "I guess they couldn't do it." We put in substantial piles, because the tracks cross at such a skew that in order to gain the necessary clearance for the tracks which were depressed it became necessary to use 32-foot stringers, and instead of putting them parallel with the track to skew them around, dividing the angle, so that 32 feet would reach from bent to bent. This made it necessary to extend the bents farther than ordinarily would have been necessary,

and to practically floor them from one end to the other with stringers.

Mr. F. C. Rossiter: I have had a little experience in laying out curves which perhaps would be interesting to you. It was rather a sad experience to me in one sense, and at the same time it gave me a chance to learn something which I would not otherwise have had. I think we learn more sometimes by our failures than by our successes.

A few years ago Nelson Morris rented a very small tract of land for repair yards, being I think 125 feet in width facing a street and extending 300 feet in depth along a main line of tracks. We were permitted to cross this street with the lead, thereby giving us a better chance to lay out our curves. The orders were to lay out the yards to hold 45 cars at a time. My first plan was for seven tracks, all running direct from the lead, with no curves the radius of which was less than 150 feet, but the yard thus planned would not hold over 35 cars. This, he said, would not do, and ordered me to make new plans, shortening the curves. I called his attention to an irregular curve in the stock yards, running around a quadrant, which near its center does not exceed an 80-foot radius, and over which I have seen the common freight cars, drawn by the shortest geared engine, pass without difficulty. Fearing future difficulty, I asked him several times what kind of cars were to be placed upon these tracks, but he evaded the answer until pressed, and then said, "These are our cars," pointing to trains passing over the main tracks adjoining, and composed of all kinds of cars, except those to be repaired in the yards. Several of these cars I measured and found that they could pass over these curves. He should have directed me to their repair yards then in use, for one hour's time spent in them would have prevented the error; but I had no idea such a yard was in existence. When we came to test the curves, they brought forward the longest cattle cars that ran into the stock yards, with roof plates extending six inches beyond the ends of the cars, with broken bumpers, and draw-bars gone. These cars were pushed into the yard with a full-sized switch engine, which could not pass over a 200-foot curve. Some of these cars were so badly injured that they could not pass over a much larger curve without destroying the roof plate. The consequence was, that all tracks had to be changed to 200-foot radius, with only five tracks in place of seven.

LXI.

A STADIA DIAGRAM.

By Morris K. Trumbull, Jun. M. W. S. E.

The "Stadia" method of making a typographical survey has attained popularity among engineers, not because there is an interesting practical theory involved, but for the reason that it is decidedly quick, accurate and comprehensive; while the notes taken in the field are, after their "reduction," admirably adapted to office use.

Since the field notes, as taken, require reduction before the map can be plotted, any method that will facilitate their reduction, so as to give results within the degree of accuracy required, is welcomed.

When an engineer has three or more stadia parties constantly at work making a survey, the reduction of the notes is no small item. With the end in view, therefore, of cutting down the amount of time required on this detail of the organized work, the accompanying Stadia Diagram was designed.

In giving a brief description of the methods used in its construction, it must be stated that every point plotted was taken from the "Stadia Tables," compiled and published by Messrs. Alfred Noble and Wm. T. Casgrain. The values found in these tables were computed from the following formulæ, deduced by Professor S. W. Robinson:

$$(a) \quad h = \frac{R'}{2R}(B-c-f)\ \mathrm{Sin}\ 2V + (c+f)\ \mathrm{Sin}\ V$$

$$(b) \quad d = \frac{R'}{R}(B-c-f)\ \mathrm{Cos}^2 V + (c+f)\ \mathrm{Cos}\ V$$

in which

R′ = Any reading of the stadia for which the horizontal distance and difference of elevation are to be obtained.

B = Length of a measured base.

R = Reading of the stadia on that base.

V = Angle of elevation or depression.

c = Distance from center of instrument to center of object glass of the telescope.

f = Principal focal distance of the object glass.

h = Difference of elevation corresponding to a reading R′ and angle V.

d = Horizontal distance corresponding to a reading R′ and angle V.

For the computation of the tables, the following values were assigned to B, R and (c+f):—

$$B = 1000 \text{ feet}$$
$$R = 1000 \text{ ''}$$
$$c + f = 1.4 \text{ ''}$$

There is nothing new in the plotting of the inclined straight line curves (which in this discussion, we will call *vertical angle curves.)* They represent vertical angles, from 0° to 8°, and distances between zero and 1,600 feet.

In plotting one of them, for say 2° 20′, the differences of elevation due to this vertical angle and rod readings of 100, 200, 300 feet, etc., were taken from the table.

Rod readings were plotted as abscissæ, and their corresponding differences of elevation as ordinates.

These points were connected and gave the vertical angle curve for 2° 20′. The same operation was performed for every angle appearing on the diagram; as the diagram then stood, only differences of elevation could be determined from it.

After the delineation had been completed thus far, it was desired to incorporate upon the same sheet a method of obtaining the *horizontal correction for distance;* and not only that this correction should be obtained from the same sheet, but that it might be determined at the same time as the difference of elevation.

Whatever may be the scale of the maps to be plotted it is almost invariably sufficient to give the results of "side shots" to the nearest tenth of a foot for elevation and to the nearest foot for distance. The latter criterion of accuracy especially aided the attempt to secure simplicity in the construction of the diagram and at the same time gave assurance that no reading would be in error by more than one-half foot.

The aim of the design was to enable the computer to tell *at a glance* what the horizontal correction should be, as he is determining the difference of elevation.

The outcome of a careful study of the means of formulating such a device was to divide the diagram into zones, within each of which the correction to be applied to the reading stadia to give the correct horizontal distance, would be the same. With the diagram thus divided it is evident that the correction for horizontal distance could be observed instantaneously when taking out the difference of elevation. Since it was only sought to obtain the correct distance to the nearest foot, the number of zones would not be excessive and the lines separating the zones would not confuse the diagram. The method of drawing these separating lines is now to be explained.

Upon any vertical angle curve a point may be fixed where the horizontal correction for distance is +0.5 ft; another where it is −0.5 ft; another where it is −1.5 ft., and so on. Taking, for example, the vertical angle curve for 2°, these points correspond with the following rod readings, or, expressing the various terms as in the general formulæ and remembering that (d − R′) = the horizontal correction for distance, we have from the tables for V = 2°:

$$(d-R') \begin{cases} = +0.5 \text{ ft. when } R' = 345 \\ = -0.5 \text{ ft. when } R' = 727 \\ = -1.5 \text{ ft. when } R' = 1111 \end{cases}$$

These points being plotted on the diagram, the correction (to the nearest foot) will be $+1.0$ ft. when $R' < 345$; 0 when $R' > 345$ and < 727; -1 ft. when $R' > 727$ and < 1111, etc. This would enable the computer to apply instantaneously the proper correction to the rod reading to give true horizontal distance *when* $V = 2°$.

A similar set of points was determined and plotted for other values of V; a curve was then drawn through the points where $(d-R') = +0.5$ ft.; another curve through the points where $(d-R') = -0.5$ ft.; another where $(d-R') = -1.5$ ft., and so on. These curves divide the diagram into the zones desired.

For any point on the diagram falling in the zone which lies between the curve where $(d-R') = +0.5$ ft. and the curve where $(d-R') = -0.5$ ft. it is evident that the reading equals the true horizontal distance within less than ½ ft.; in the diagram this zone is marked 0 on the left hand vertical angle curve and "No Change" in the lower margin.

For any point in the diagram falling in the zone which lies between the curve where $(d-R') = -0.5$ ft. and the curve where $(d-R') = -1.5$ ft. the reading reduced by 1 ft. will give the true horizontal distance within less than ½ ft.; in the diagram this zone is marked -1 (the correction) on the left hand vertical angle curve, and also in the lower and right hand margins. The succeeding zones are marked in a similar manner.

In the zone falling below the correction curve passing through the points where $(d-R') = +0.5$ ft., the reading must obviously be increased by 1, or more, to give true horizontal distance. By the formulæ it will appear that the maximum correction occurs when $V = 0$ and $R' = 0$ and in this case $(d-R') = +1.4$; hence at all points below the correction curve of $+0.5$ ft. the readings are to be increased by unity to give the true horizontal distance within the required limit. This zone is marked $+1$ on the left hand vertical curve and in the lower margin.

The use of the diagram will be illustrated by the following examples:—

1. Let it be required to find the horizontal distance and difference of elevation when $V = 2°22'$ and $R' = 452$ feet.

Enter the diagram at the bottom with 452 feet.

Follow up the vertical for this distance (estimating the 2 feet) till it intersects the straight line curve for $2°22'$ (this angle may be estimated). It will be noted at a glance that this intersection falls in the zone labeled *No change*. Therefore the correct horizontal distance is 452 feet. Then follow across horizontally and it will be seen that the difference of elevation is 18.7 feet.

2. For $V = 4°45'$ and $R' = 810$ feet the diagram shows that h

66.9 feet and the horizontal correction = −5 feet. Therefore the correct horizontal distance for this shot is 805 feet.

The great majority of stadia readings fall within the limits of the diagram; those that fall outside (and they occur very seldom even in quite rough country) may be reduced by the use of stadia tables, or by the given formulæ.

The diagram is accurate within the limits required and admits of the development of considerable speed even with novices. One feature of its use is that members of a stadia party, not ordinarily utilized for "office work," can be broken in so as to become reliable computers.

The diagram has been in constant use since last March.

In case the stadia boards employed are graduated according to the metric system, a complete diagram may be constructed to correspond with the metric unit in length, As far as the determination of the difference of elevation is concerned, however, the accompanying diagram will serve, but since the true horizontal distance is not directly proportional to the reading of the board the horizontal correction part of the diagram cannot be used. It will therefore be found expedient to delineate a new diagram, and provide at the same time for a greater degree of accuracy in the estimation of tenths as a consequence of the enlarged unit. If, according to the prevailing custom in this country, where the metric unit is used for graduation of stadia boards and the differences of elevation desired in feet, then the present diagram fails to suffice at all and a new one must be constructed.

GRADUATION OF STADIA BOARDS.

It is found in practice that the most convenient distance between the stadia wires of a transit is that which will intercept ten feet on a rod held vertically at a distance of a thousand feet from the transit. It is practically impossible for the instrument maker to space the wires so precisely that the rod intercept will be exactly the amount desired. A small variation is not important, however, if the board is so graduated as to provide for this mechanical inaccuracy, thus avoiding the introduction of a correction coefficient to make the readings correspond with the tables or diagram. To effect this, it is advisable to fix the unit for graduating the stadia board with reference to the particular transit to be used with the board.

There are two distinct methods of determining the unit for graduation.

According to one method it follows that every stadia reading for distance, after being corrected for the inclination of the telescope from the horizontal, is yet in error by the amount of the horizontal projection of the instrument constant $(c+f)$. The aim in staking out a base line, preparatory to testing an instrument is, to so provide, that the effect of $(c+f)$ will not enter into the

results of the observation to be made. The distance (c+f) for that instrument is measured out from the plumb lime and then from this point intervals of 100 feet are chained and stakes set.

The following formulæ are the basis of the method, and are used in reducing the readings that are afterwards made in taking topography. Tables have been constructed whose values have been computed from these formulæ:

$$h = \tfrac{1}{2} R' \operatorname{Sin} 2V + (c+f) \operatorname{Sin} V$$
$$d = R \operatorname{Cos}^2 V + (c+f) \operatorname{Cos} V$$

The notation used is the same as in formulæ (a) and (b) on page 1399.

According to the other method of graduation, and it is the only one we will consider farther in this discussion, the unit value, as determined, is such that the error due to the constant (c+f) is seldom greater than 1 ft.

For this method Professor Robinson's formulæ (a) and (b) are applied.

A brief discussion of two applications of the second method, which is based upon Professor Robinson's formulæ, is here presented as supplemental to the diagram discussion, and possibly as being of general interest to the JOURNAL'S readers.

It is preferable in using these formulæ for the computation of tables that the stadia boards for whose readings the tables are to be used for reduction, should read correct at some one distance.

The unit we will consider is feet, although the methods apply to the metric system as well.

The first and older application is an approximate one, yet possessing a degree of accuracy that is sufficient for the great majority of shots.

A day is chosen when the air is calm and steady. A party of say four men proceeds to the field with transit, level-rod (with two targets), steel tape and usual apparatus for staking out a base line. Stations are set on smooth level ground at intervals of 100 feet from the center of the instrument. The lower of the two targets is fixed, the other movable. With the rod held vertical on the first 100 foot station, the lower stadia wire is set on the fixed target, after which the rodman, by signal, clamps the movable target at the position where it is cut by the upper stadia wire. The length on the rod, subtended by the extreme cross-wires, is a value for the space covered at 100 feet.

The same is done at the 200, 300, 400 foot marks, etc. The whole operation may be repeated, as many times as desired, in order to discover large errors, as also to obtain mean values at each station; these mean values will not be in exact ratio, for the reason that the space intercepted on the rod by the stadia wires does not vary exactly with the distance.

In determining the unit value for graduating the boards, the

mean readings obtained at the respective stations are added, and the total divided by the summation of one hundred foot intervals determined.

This method distributes (c+f) among the several determined distances, and is the one that has been most used in the past for obtaining the unit value for graduation of stadia boards.

The value so obtained is laid out successively upon the face of the board, and these spaces are then subdivided into tenths or smaller subdivisions and marked with such symbols as the engineer prefers.

In the second application of Robinson's formulæ to the graduation of stadia boards, the condition is first laid down that the reading shall be the horizontal distance, at some given distance from the instrument on level ground. The distance usually taken is 1000 ft. If perfect observations could be made at this distance the unit for graduating the stadia boards could be determined satistactorily on a base line of this length; unless, however, the telescope is of unusual power and the air very clear better observations can be made at a less distance; if taken at such less distance account must be taken of the (c+f) factor, because the distances and readings are not in exact ratio. The formulæ, or preferably the tables based on them, furnish readily the data for laying out a base line with hubs at such intervals that the readings on them will be in simple ratio to the readings on the 1,000 ft. base and can be used with equal theoretical and greater practical accuracy for determining the unit for graduation. These intervals must be calculated before the field observations for determining the unit can be commenced. The preliminary computations are as follows:

Say that (c+f) for the instrument is 1.4 feet, and it is desired to have the set of boards read 1,000 feet upon a measured base of 1,000 feet; that is to say, for 1,000 feet R B. With these values it will be found, in applying the formula for distance, that when the rod reading is 100 feet, the "actual distance" (d) of the rod from the center of the instrument is 101.26 feet. Likewise, when R′ is 200 feet, the actual distance of the rod from the center of the instrument is 201.12 feet. Calculating the values of d for successive rod readings of 300, 400 feet, etc., the actual distances are found to be 300.98, 400.84, etc., making each interval, with the exception of the first one 100 − 0.14 feet.

The first interval is 100 + 1.4 − 0.14 feet, as will readily be perceived upon solving the formula for distance using R′ 0, whence d 1.4 feet, or (c+f). It will be observed that 0.14 is just one-tenth of the (c+f) constant, thus this amount, 1.4 feet, is equally distributed over the successive intervals of the base line.

Consequently, the base will be staked out as follows: Calling the point at the distance 101.26 feet, Sta. B_1, that at the distance 201.12 feet, Sta. B_2, etc.

Point Held on.	Distance from Instrument Center.
Sta. B_1	101.26 Feet.
" B_2	201.12 "
" B_3	300.98 "
" B_4	400.84 "
" B_5	500 70 "
" B_6	600.56 "
" B_7	700.42 "
" B_8	800.28 "
" B_9	900.14 "
" B_{10}	1000.00 "

Now, just as was desired, points have been secured upon which to hold the level rod for the purpose of measuring the distance intercepted on the rod between the two stadia wires of the transit; if the intercepts are measured correctly the intercept at B_2, B_3, etc., will be exact multiples of the intercept at B_1. Let these intercepts be designated I_1, I_2, I_3, I_4, etc.; then, if the work is correct

$$I_1 = \frac{I_2}{2} = \frac{I_3}{3} = \frac{I}{4}$$

etc., and this constant quotient is the unit for graduation desired.

These preliminary calculations being made and the base line staked out as described, the party proceeds to the field equipped as for the previous method, and the instrument is set up at the zero end of the base line.

Five or six shots are taken on the level-rod held vertically on Sta. B_1 (two targets being used as before). These readings should agree; if they do not agree exactly, but differ by small amounts, a mean may be taken as the reading on that station; if the divergence is too large a new set of readings should be taken.

The rod is then held on station B_2 making the same number of observations as upon Sta. B.

These should agree with one another, while $\frac{I_2}{2}$ should agree with the corresponding ratio determined at Sta. B_1.

The same is done upon Stations B_3, B_4, B_5, etc., and including Sta. B_{10}, which latter it will be remembered is exactly 1,000 feet from the center of the instrument.

If the test should be made on a day when the atmospheric conditions are such as to cause poor definition in reading the rod at the last station or two, then it may be found advisable to omit the observations at these points. Manifestly this does not affect the principle.

If it should be found that the several determinations $\frac{I_1}{1}$ $\frac{I_2}{2}$ $\frac{I_3}{3}$,

etc., which should be equal, have varied slightly, a mean of all of them will give the unit value for graduating the boards for that instrument. This value may be called the stadia wire constant of that instrument.

The next step is to lay out the boards. They have already been constructed of clear, well-seasoned pine, about 4½ inches wide, one-half to three-quarters of an inch thick, and 12½ feet long. The ends are shod with light strips of iron and the back of the board reinforced by a T-brace running nearly the full length. Three or four coats of white paint have been given to the boards.

Beginning about three inches from the bottom the unit value is laid out successively to near the top of the board, and then these several spaces are subdivided into tenths. The cut, Fig. — shows one of the forms of symbol used. The smaller diamonds are 3½ inches wide while the others are all 4 inches across, including the 100 foot mark symbol. Fifth and tenth 100 foot marks are painted red to distinguish them, and all the other symbols are painted a dull black.

Fig. 579. Sample of graduation, about 1-9 of full size.

This outlines the program completely for any one instrument. The same base is used and the same method of observation is gone through with for every instrument that is to be employed for stadia work; consequently each instrument has its own set of stadia boards and the latter should be numbered to correspond.

By this application of the method all graduations are theoretically correct and all notes taken may be reduced (with theoretical corrections) by use of the formulæ or stadia tables.

The theoretical inaccuracy of the older application of Robinson's formulæ follows from the fact that the errors due to $(c+f)$ and the wire constant as well, are dealt with in graduating the boards as if both always bore a constant relation to one another, which they do not. Furthermore, the fundamental inaccuracy of this application is clearly seen when we attempt to determine the length of base upon which the stadia boards for any particular instrument will read correct. The formulæ and tables assume by hypothesis that this distance is known, but it is a fact that it can only be determined by tentative method when this application has been employed, and even then only approximately. Then when R for B has been determined it will probably be found that these values differ appreciably from what would satisfy the formulæ, while all the instruments having rods thus graduated for them would neither furnish values that would satisfy the formulæ nor agree with one another in this respect.

On the other hand, in the case of the latter application *every* instrument, when used with the set of boards graduated for it, is known to read 1,000 at a horizontal distance of 1,000 feet, whereas a shot taken on any measured base will give a reading that involves only (c+f) and the vertical angle V, and will, therefore, satisfy the formulæ.

While the older application gives results sufficiently accurate for ordinary shots, the later one has the point in its favor that a theoretical principle is used where it gives *at least* as good results as the approximate one.

WRITTEN DISCUSSION.

By Charles L. Harrison, Mem. W. S. E.

The diagram constructed by Mr. Trumbull for reducing stadia shots greatly facilitates that work. It has the merit of being compact and handy and enables the computers to get the difference of elevation and the horizontal distance with one operation. The diagrams generally used for this purpose require separate operations for each of these determinations. The distances as read can be corrected to the nearest foot, which means that no shot will be in error more than one half foot, but corrections can be estimated closer if desired. But when the conditions of a survey require that distances must be measured closer than to the nearest foot, other methods than stadia must be used. The elevations can be reduced to the nearest one-tenth foot. The diagram presented is constructed to reduce shots which are not more than 1,600 feet in length and not more than eight degrees in vertical angle but the principle may be extended to any desired limits in each direction.

It is based on the stadia tables computed by Messrs. Noble and Casgrain (which are the only extensive tables published giving both elevations and distances in feet) and is intended to facilitate the reduction of side shots—the most important shots being reduced from the tables direct. They have been in constant use by several field parties for eight months, so that a good estimate can be made of their efficiency. An average computer can reduce fifteen pages of notes, containing twenty shots each, in one hour, and a rapid computer has reduced twenty-five such pages in one hour. A greater speed than this can be made for a short time. An estimate then of from four to seven shots reduced per minute by one computer, for the time actually working, is well within what has been accomplished. Considering the fact that these reductions involve determining both the difference of elevation between the instrument station and the point on which the rod is held, and the correction for horizontal distance due to vertical angle and (c + f) it is really a very rapid method of making these reductions.

The method adopted for determining the unit value of the

stadia wires should conform to the theory on which the tables, to be used in reducing the notes, are computed. The effect of (c + f) on horizontal distances is of so little moment that it may be neglected altogether on side shots without materially affecting the accuracy of the work, but when the elevations are carried from instrument station to instrument station by vertical angle it is very important to have the true distance between these stations, especially when the vertical angles are large, for then an error of one or two feet in the distance would make a material error in the difference of elevation of the stations.

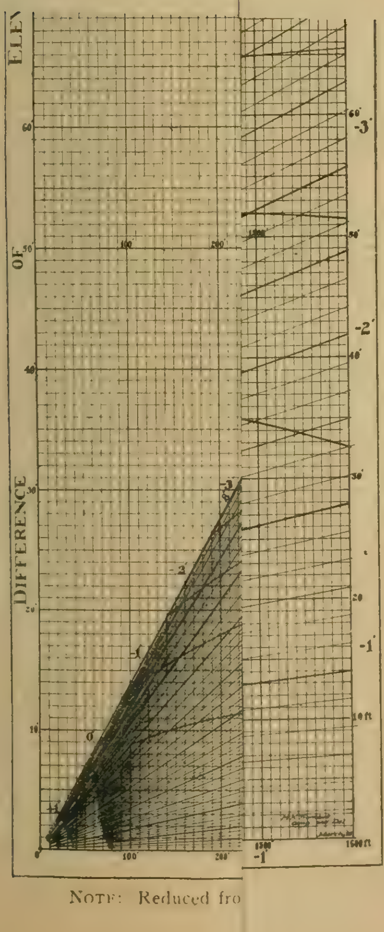
There is hardly justification for an engineer approximating when correct measurements are to be had without additional labor or cost. The method of determining the stadia unit described by Mr. Trumbull seems to be correct and it may be of interest to the members of the society to know the results obtained on actual surveys when using stadia rods graduated for each instrument in accordance with this method.

The writer has been engaged since last April in making a survey (using stadia methods) under the direction of the U. S. Board of Engineers on Deep Waterways, for developing a contour map of a line over one hundred miles long and from one-half mile to one mile in width. In brief, the method used was to measure a base line with standardized steel tape along the general line of the route, using a spring balance for determining the tension on tape and correcting for temperature. Observations were made for azimuth about every five miles. Circuits were run from a station on the base and closed on the base at the same or some other station as the conditions might require. The distances both forward and back were measured by stadia and the vertical angles were also read in both directions. The mean of the two distances read and the mean of the two vertical angles were used in reducing the notes. The co ordinates of every stadia station in each circuit were computed and compared with the co-ordinates of the base line. The base line measurements were assumed to be correct and were used as the standard for comparison. The elevations were carried by vertical angle. The work was done by four separate field parties and seven different observers, so the results fairly show the accuracy which may be expected in this kind of work when done by an average good observer.

Number of circuits run......................290
Average length of circuit................7,944 feet.
" number of stations per circuit...........8.
" error in latitude " " ....3.73 feet.
" " " departure " " ....2.79 feet.
Average error in elevation per circuit....0.167 feet.

One circuit, not included in the above, over 53,000 feet long, closed with an error in elevation of 0.4 ft. It will be seen therefore that elevations can be carried in stadia work by vertical angles within the usually required limits of error.

CORRESPONDENCE ON THE PAPER—XLVI.*

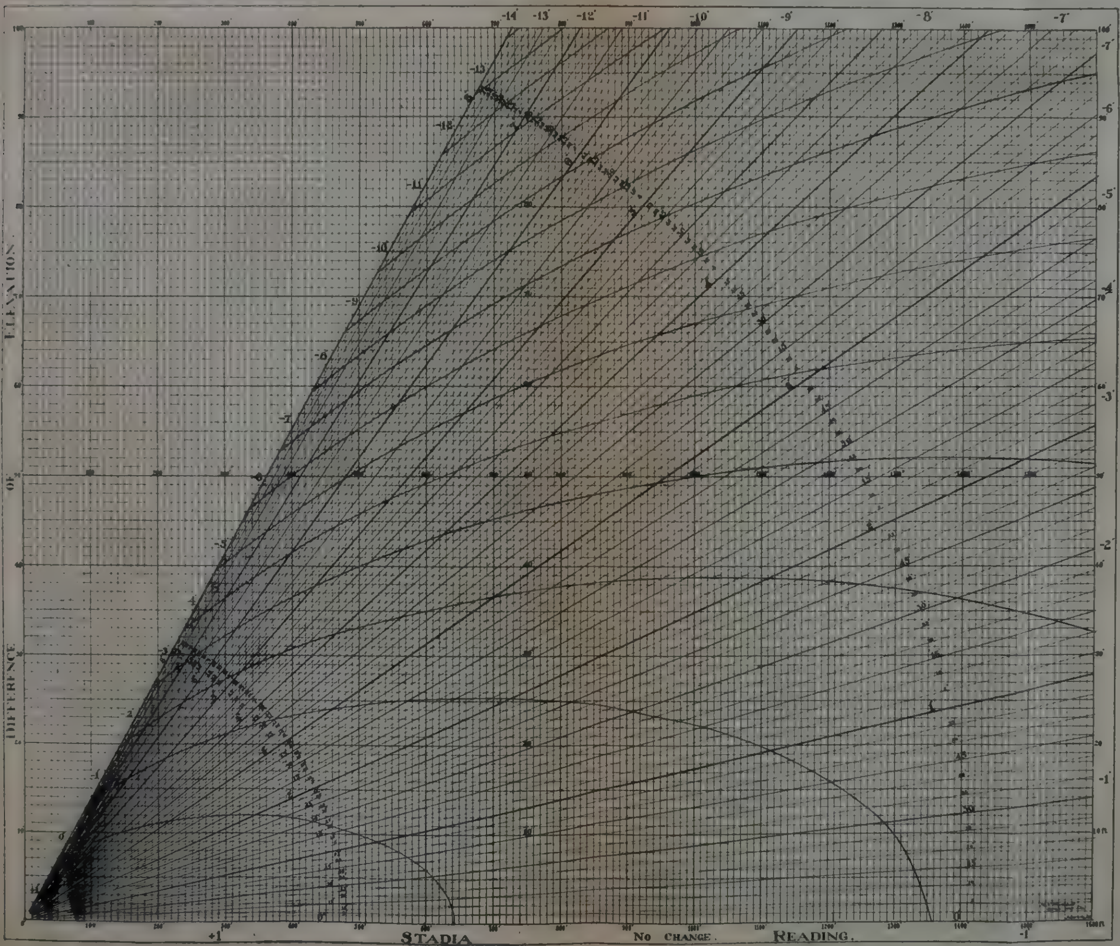


NOTE: Reduced fro

FIG. 580. TRUMBULL A STADIA DIAGRAM.

STADIA DIAGRAM.

Entering the Diagram at the bottom with **Stadia Reading for Distance,** the Computer will follow up the line till it intersects the diagonal representing the **Vertical Angle** desired He will note between which curved lines this intersection falls, thus giving **Correction for Horizontal Distance;** then from the same intersection follow across horizontally to obtain **Difference in Elevation.** The Curved Lines mark off for any Vertical Angle the several **Critical Distances** at which the Horizontal Correction **changes** from 0' to -1', from -1' to -2', etc., as indicated in the margin.



NOTE: Reduced from 35 x 21 in.

CORRESPONDENCE ON THE PAPER—XLVI.*

From F. W. SETTAN, Mem. W. S. E.

About two years ago I received the appointment as Chief Engineer for the U. S. Government Building at Chicago. Soon after I had entered the service in that capacity and had made myself familiar with the preliminary design of the building, Mr. Henry Ives Cobb, Architect for the U. S. Government Building, informed me that Mr. George S. Morison had suggested to him the placing of the building upon a concrete and masonry foundation on caissons, running them down to hard pan or rock. I heartily endorsed this suggestion and apparently Mr. Cobb seemed well pleased. Mr. Sooy Smith says, after the introductory part of his paper, that three different methods of foundations were studied and compared, namely: 1st, Masonry on platforms of steel beams and concrete; 2nd, Wells sunk to hard pan and filled with concrete or rubble masonry; 3rd, Piles driven to hard pan, wooden grillage, concrete and masonry.

Regarding the first method I may state, that from the time I took charge of the engineering work of the building, such a plan for foundations was not considered, and I am greatly surprised that it should be stated that it was rejected on account of being unsafe and too expensive. Neither was the third method favorably considered until Mr. Sooy Smith received the appointment as Engineer in Charge of Foundation, in April, 1897.

The only method that had received attention up to that date, was that suggested by Mr. Morison, and the only computations, made by me, show that nothing but concrete and masonry foundations were considered. After Mr. Cobb was apparently convinced that the pile foundation was preferable, I reluctantly made the modified computation for the latter and designed the same on the suggested bases, a load of 30 tons on the enormously long piles of 45 to 50 feet being assumed as safe.

It is a fact that the unreasonably high load for these unusually long piles was adopted by consulting similar works, executed in Europe, probably under different circumstances. In some cases piles may be loaded to 60 tons, though I never heard that a pile has ever safely carried 100 tons, but I know of a case in France where piles were loaded to 77 tons, the structure being a bridge, which collapsed on account of the piles being overloaded. Assuming this figure as the ultimate resistance of a pile the factor of safety in this case will be a trifle less than 2.5, which I think is rather small and inadequate for any kind of construction.

It is stated that according to Trautwine's formula and the ob-

*Paper on "Foundations for U. S. Government Post Office and Custom House Bldg., at Chicago," prepared by William Sooy Smith and published in October, 1898, Journal. See page 1216.

served penetration from the last blows, the piles can sustain a load of 136.75 tons, which would render a factor of safety a little more than 4, as the piles in some places will have to carry a load of nearly 32 tons according to my calculations. In the description of the preliminary borings, it is said that after a certain depth was reached hard pan was struck, into which it was impossible to bore with a common wood auger; however, no statement is made at what depth the supposed hard pan was reached, when piles were driven, though data are given of the penetration after a certain number of blows. Looking over these figures it shows that the penetration of the piles under the last blows is rather small and certainly the piles had reached hard pan before the last few blows were struck; and as it is impossible, according to the borings, to penetrate the hard pan with a square-ended post, it is possible that some of these piles were broken at a weak spot under the superfluous blows. I doubt very much whether such defects could have been readily detected. It is obvious that in a pile foundation, no matter how carefully it is executed, there is nothing to indicate whether the piles were left in a perfect or injured condition; once driven they do not permit of any underground inspection and are beyond control.

Another difficulty I encountered in my computation was to get the piles uniformly loaded, which is almost an impossibility. If I remember some of the figures correctly, the loads vary in the different places from about 22 to 32 tons; in some cases the conditions required a certain number of piles, when the load was rather light, and when the loads were high there was a lack of space for the required number of piles. Such a wide difference in the loading of the piles will certainly cause an uneven settlement in spite of the supposed large factor of safety. While it need not be anticipated that such a settlement may cause destruction of the building, it will be enough to cause bad cracks and put it on the same level as its predecessor.

An interesting account is given about the displacement of the soft clay by the piles and it was ascertained that the same volume of clay was excavated and removed as was occupied by the piles. This plainly shows that the soil maintained its original compactness and was not compressed in any way whatever. The piles are now standing in a doughy mass, which will yield in any direction it is forced. Under such circumstances the piles have no side bracing, as is asserted in the paper, and simply act as columns transmitting their loads to the hard bottom. It is unnecessary to demonstrate how much of a load columns of the dimensions of these piles can safely carry. If I remember correctly a rough computation showed that such a column could carry, using 4 as a factor of safety, a load of 10 tons.

In contrast to the unfitness of pile foundations for very heavy buildings on a deep, soft soil, let us see if concrete and masonry in caissons or wells is of more advantage. Under any and all cir-

cumstances the foundation can be correctly proportioned for the load it has to carry. After caissons or wells are sunk the soil can be carefully examined and obstacles removed. The construction of masonry and concrete can always be inspected, faulty work is easily detected and can be replaced, the material will never decay and after it has set it never changes its volume; for these reasons buildings must have an even settlement which will prevent the walls from cracking.

Now, regarding the cost, it is claimed that $100,000 was saved for the Government by the method of pile foundations. This fact may be undisputed, but the question is, what will the Government have to pay for the constant repair of cracks and other defects and a subsequent removal of the building on account of an insufficient and badly proportioned foundation? Even if $200,000 more had been spent on a concrete and masonry foundation, the money certainly would have been well invested and the building would stand firmly, and not on a huge wood pile.

CLOSURE.

By William Sooy Smith, Mem, W. S. E.

As to the narrative portion of Mr. Settan's discussion nothing need be said. It throws no new light on the subject. The character of the materials through which the piles in the foundation of the Post-Office Building were driven is clearly set forth in the paper, and its behavior while the piles were being driven is also described. A careful study of the facts will lead to the conclusion that there is very great lateral pressure of the soil developed by the displacement due to the driving of the piles. As stated, there are spots or layers of stiffer clay found in the soft clay overlying the hard pan—and the piles are driven through the materials thus interstratified.

The soft clay is made up of minute particles saturated with water. Neither the solid nor the fluid particles are compressible —and when the piles were driven the earth was displaced, as stated. The lateral pressure produced was and will continue to be very great, effectually preventing any flexure of the piles regarded as columns of support. The actual test made on the Public Library lot, as described, and the experience had with the pile foundation of that building, and many others since constructed prove that no danger whatever need be apprehended from this cause.

The idea that some of the piles might have been broken during the driving will cause no alarm to anyone having experience in pile-driving, as a sudden increase of penetration would at once clearly indicate the fact. And no part of the apparent penetration was due to any "brooming" of the point, as the piles were not pointed.

The moment the piles reached hard pan it became perfectly

evident from the sudden increase of resistance and great reduction in penetration. Concrete columns make an excellent foundation, and under certain circumstances they are preferable to piles, especially where piles cannot be driven without endangering buildings near by. We are using them wherever these circumstances exist.

But piles under water are everlasting, and when the compression due to their elasticity has taken place under the loads put on, there is no further settlement, and as the total compression of a fifty foot pile due to this cause is but 2½ inches, and almost absolutely uniform throughout large numbers of piles, there can be no appreciable difference in settlement—much less any inequality that can endanger a bnilding.

The concrete column foundation is much more expensive than the equally strong and durable pile foundation, and should not therefore be preferred, except when the existing conditions preclude the use of piles.

A pile foundation can always be correctly proportioned for the load it has to carry, simply by dividing the total load by the safe load per pile, and using the number of piles indicated by the quotient, and one for the fractional remainder, where there is one.

The risk of inferior materials and workmanship is greater in the case of the concrete column—as it is well known that it requires a combination of skill, experience and honesty to secure first class concrete work. Whereas the very process of driving a pile is a good test of its soundness and strength, and its resistance affords ample assurance of its sustaining power.

The experience already had in the behavior of pile foundations of heavy buildings in the city of Chicago fully justifies the preference our best architects are now giving them, and they are rapidly gaining universal confidence and favor.

LXII

EXCURSION TO UNIVERSITY OF ILLINOIS.

Report of the Entertainment Committee.

Upon the invitation of the president and faculty of the University of Illinois and by the courtesy of the Illinois Central Railroad Company in placing a special train at our disposal, about one hundred and thirty-six members of the society and ladies made an excursion to Champaign and Urbana on Friday, November 11th. We left Central Station on the special train at 9:15 A. M. With us were four trustees of the University, the number including Mr. R. P. Morgan, a member of the Western Society, and Mrs. Flower, well known to the educators and voters of this city.

At Kankakee we were joined by Mr. Dwight C. Morgan, member W. S. E., and Mr. Breckenridge, Professor of Mechanical Engineering in the University. Upon our arrival at Champaign, at one o'clock, P. M, we were met by a delegation of professors from the University, prominent among the number being Mr. I. O. Baker, Professor of Civil Engineering and a member of the Western Society.

Under the guidance of the professors we boarded the electric cars that were waiting for us at the station and were soon landed on the University grounds, in front of Engineering Hall. Upon entering the hall we were cordially welcomed by Dr. Draper, president, and other members of the faculty.

After divesting ourselves of our wraps, and an exchange of greetings, we were invited to the physics laboratory to partake of the bountiful repast prepared for us to fortify us for the inspection work before us and incidentally test some of the products of the farm belonging to the University. Many of us can testify that they raise good things on that farm and that some one connected with the institution knows how to make good apple pie, as well as delicious coffee.

After satisfying the wants of the inner man and a short

Fig. 581.

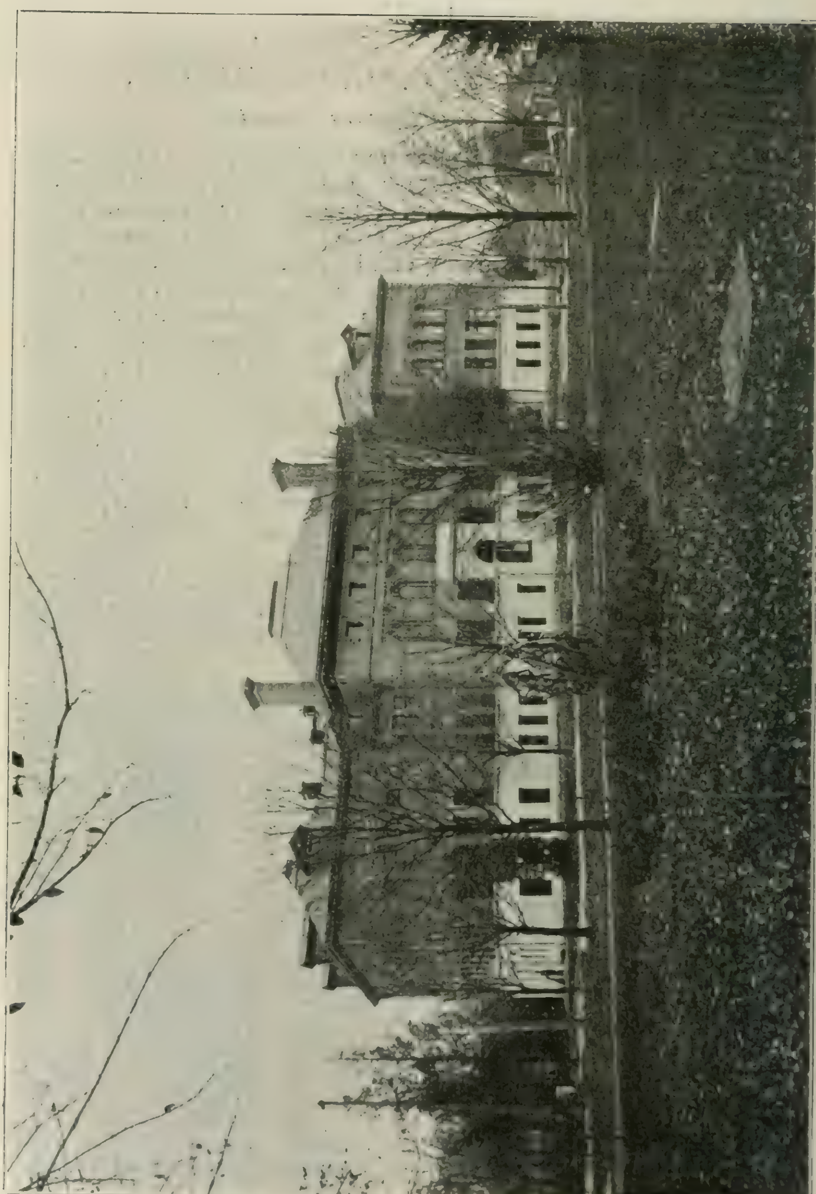


Fig. 582. Engineering Hall, University of Illinois.

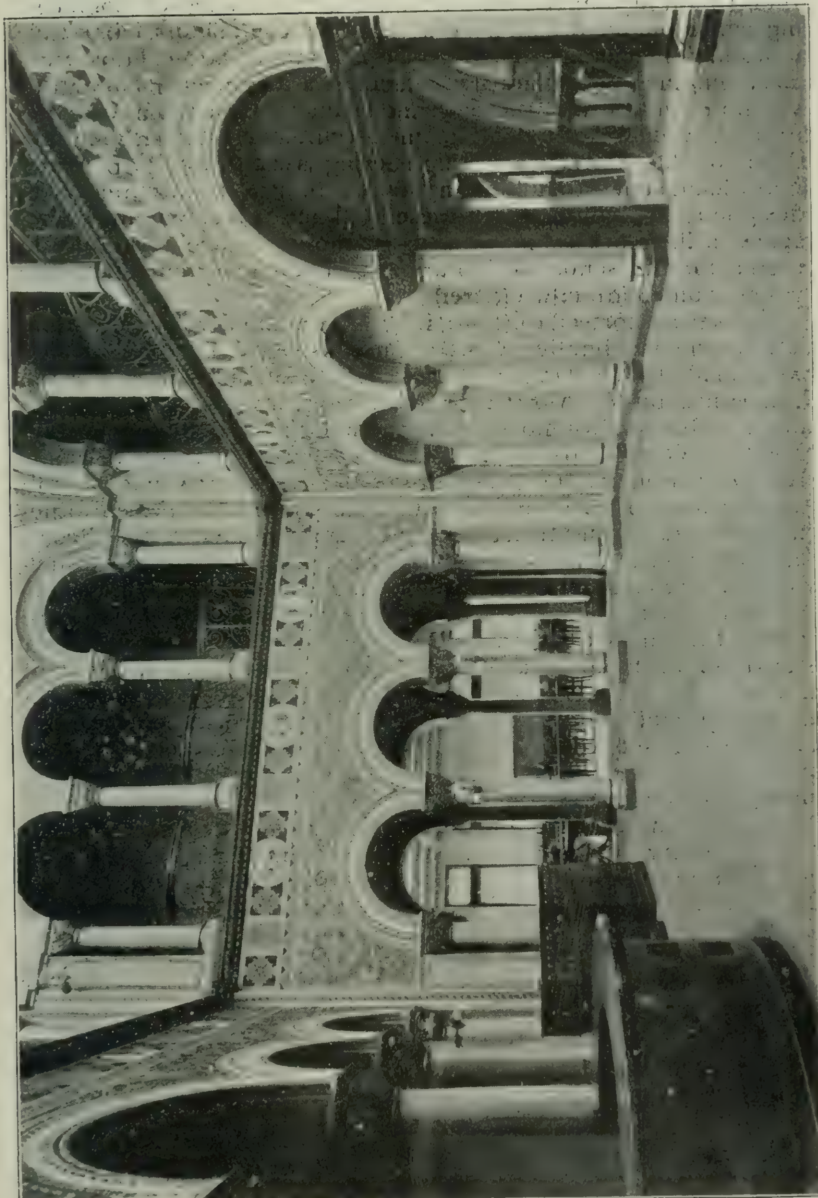


Fig. 583. Interior View of the University Library.

address of welcome by the president of the University, under the guidance of Dr. Draper and several professors, we visited the University buildings, exclusively occupied by the College of Engineering, which included Engineering Hall, the wood shops, laboratory of applied mechanics, machine shops, foundry, forge shops, electrical engineering laboratory, mechanical engineering laboratory and boiler house, also the large and beautiful library hall designed by Prof. Ricker, at the head of the Architectural Department and Dean of the College of Engineering, assisted by Prof. White. It is a handsome stone building and a credit to its architects and designers. It contains at present about 45,000 volumes with space in the stock room for as many more. It also contains the rooms for the school of library instruction in which thirty-five young women are now entered.

We were escorted from the library to the physics lecture room and during our conference there remarks pertinent to the occasion were made by Dr. Draper, Professors Ricker, and Baker for the University, by Mr. Morgan for both the University and Society, and by Messrs. Morehouse, Hunt, Randolph and others for the Society. At the close of the conference and after a vote of thanks by the visitors to the president and all those who had so ably assisted him, for their kindness and courtesy and the pleasure they had given us during the day, we were again invited to the physics laboratory, where we were served with a hearty lunch, to which, so far as your committee was able to judge, the party did full justice.

Upon leaving the hall at 6:15 P. M. we were taken by the electric cars to the railroad station where we found our train waiting with steam up to take us to Chicago where we arrived safely at 10 o'clock P. M. It was a red letter day for those who attended the excursion and we regret that so many of the members were unable to go, and especially that our worthy president and more members of his cabinet or advisers could not have been with us on this memorable and felicitous occasion.

Your Committee desire to express their thanks to the members of the Society for their generous support and to all of the party for their promptness and cordiality during the trip, and we trust some action will be taken by the Society for a special expression of thanks to the President and Faculty of the University and the Illinois Central Railroad Company for the kindness and courtesies extended.

A. W. Fiero,
Jas. F. Lewis,
W. J. Karner,
Chas. F. Foster,
H. N. Elmer,
Entertainment Committee.

ABSTRACT OF THE MINUTES OF THE SOCIETY

SPECIAL MEETING—OCTOBER 19th, 1898.

A special meeting (the 392d) of the Society was held in its hall Wednesday evening, 19th of October, 1898, President Alfred Noble in the chair, present sixty members and guests, ladies and gentlemen.

There being no business to transact, Mr. Geo. S. Morison proceeded at once with his paper on masonry—illustrating his subject with a large collection of views by the stereopticon.

Adjourned.

At a meeting of the Board of Direction, 20th of October, 1898, the following applicants were declared elected to active membership in this Society: Chas. H. Mercer, Walter A. Rogers, Joseph H. Prior, John H. Warder and Edwin J. Rosencrans.

REGULAR MEETING—NOVEMBER 2d, 1898.

A regular meeting (the 393d) of the Society was held in its hall, Wednesday evening, 2d of November, 1898, President Alfred Noble in the chair. Thirty members and guests present. The minutes of the previous meeting were read and approved.

The Secretary read a letter received from Dr. A. S. Draper, President of the University of Illinois, Champaign, Ill., inviting the members of the Society and their ladies to visit that institution on Friday, 11th of November, 1898. Mr. W. J. Karner, for the entertainment committee, stated that the invitation had been accepted and read a letter from the Illinois Central Railroad Co., tendering a special train for the occasion.

The papers of the evening being in order, that on the "Construction of Retaining Walls of the Sanitary District of Chicago," by Mr. J. W. Beardsley, was read by Mr. Geo. M. Wisner, Mr. Beardsley being absent. At the conclusion of the reading the President read a discussion of the paper prepared by Mr. Chas L. Harrison, who was in charge of the Lockport division when the work described was done. Mr. L. K. Sherman also added to the discussion. Prof. Chas. V. Kerr, of the Armour Institute of Technology, then read a paper which he had prepared on the "Berthier Method of Coal Calorimetry," illustrating his subject with stereopticon views, and giving verbal descriptions and explanations.

Adjourned.

ADJOURNED MEETING—NOVEMBER 9th, 1898.

An adjourned meeting (the 394th) of the Society was held in its hall Wednesday evening, the 9th of November, 1898. In the absence of officers the secretary called the meeting to order. On motion duly seconded, Mr. W. H. Finley was elected chairman.

The track elevation of the Pittsburg, Ft. Wayne & Chicago Railway was described by Mr. W. H. Coverdale—in charge of that work—aided by a large number of stereopticon views.

At the conclusion of Mr. Coverdale's description, Mr. John O'Neill made extended remarks on various features of track elevation in Chicago from the inception of the work. Mr. H. W. Parkhurst followed with a paper on the track elevation of the St. Charles Air Line, accompanying his remarks with views of the work at different points. Mr. Dey, of the L. S. & M. S. and C. R. I. & P. railways, was called upon in the absence of Mr. L. H. Clarke, and gave explanation of the views shown of that particular work.

The Chair then called for discussion of the papers presented October 5th. At this point Mr. L. H. Evans arose and said: "Before it is too late, I wish to offer a motion that a vote of thanks be extended to Mr. Condron for his able efforts in getting so many excellent papers presented before the Society on the subject of Track Elevation and in having the same so well illustrated. I know there is a great deal of work connected with this of which he has not complained."

The foregoing motion was seconded and carried.

MR. CONDRON: I wish to thank the Society for the vote of thanks. Mr. Chairman, it seems to me that the hour is too late for anything further this evening. There has been no opportunity for oral discussion on any of these papers, and as there has been a great deal of effort made by the publication committee to get this matter together, not only for the meetings, but for the journal, it would be well to have this discussion carried over till the next meeting, which occurs one week from tonight. There is only one paper to be presented at that time and that is brief, although a very interesting one, it will probably not call forth any discussion, as it is on a foreign subject. Therefore, I move that the discussion of papers on Track Elevation be made the order of business for the next meeting of the Society.

The motion was put and carried.

Adjourned.

SPECIAL MEETING—NOVEMBER 16th, 1898.

A special meeting (the 395th) of the Society was held in its hall Wednesday evening, the 16th of November, 1898, Vice-President A. V. Powell in the chair. The Secretary made report of the action of the Board of Direction confirming appointment of a committee on the death of DeWitt C. Cregier, consisting of Messrs. Wm. Sooy Smith, Sam'l G. Artingstall, Benezette Williams, A. W. Wright, Rob't W. Hunt and L. P. Morehouse to attend the funeral.

Mr. Horace E. Horton presented the following resolutions: "We are reminded of the uncertainty of human life by the death of our late fellow member, Mr. DeWitt C. Cregier, on the 9th of November, 1898. Mr. Cregier was a Past-President of the Western Society of Engineers. It surely is desirable that the Society take appropriate notice of his death. Therefore I move: That a committee be appointed by the Chair to recommend to this Society such action as may properly commemorate the life and services of the late DeWitt C. Cregier, as an engineer, as a member of the Western Society of Engineers and as a citizen.

"In making this motion, I also make the request that the Chair appoint as members of such committee, gentlemen more immediately associated in active work in the Society, as well as in personal acquaintance with Mr. Cregier, than it has been my privilege to be." The motion prevailed, and the Chair immediately appointed as such committee, Messrs. Wm. Sooy Smith, Benezette Williams, Augustine W. Wright, Samuel G. Artingstall and L. P. Morehouse, stating that all these gentlemen were Past-Presidents of the Society, except Mr. Morehouse, who was its Secretary for many years.

The Chair then announced that the meeting was called primarily for the discussion of the papers on track elevation. Several gentlemen were called upon to open the subject, Mr. E. H. Lee brought up two questions: 1st, that some use concrete wholly for retaining walls, abutments and coping, while others use rubble masonry for retaining walls. Another question was as to the relative economy and value from an engineering standpoint of the different girder floors that have been adopted. An animated discussion developed on the line of concrete, Messrs. Lee, L. H. Evans, the Chair, Curtis, Rogers, Bremner, Roberts, Condron and others participating.

Mr. Karner rose to explain the non-appearance of the paper on the Manchester Ship Canal. The slides to illustrate the paper had not come to hand. It was decided to postpone the paper till a later date.

Mr. F. C. Rossiter followed with interesting experience in laying out curves. A call was then made for the views of the 16th street crossing, and

Mr. E. H. Lee gave verbal description as the successive pictures appeared on the screen.

Mr. Karner then read report of the Entertainment Committee on the excursion to University of Illinois at Champaign, Ill.

On motion the report was accepted and the Chair instructed to appoint a committee to draft suitable resolutions of thanks to the President and Faculty of the University of Illinois and to the Illinois Central Railroad Company for the courtesies extended.

Adjourned.

REGULAR MEETING—DECEMBER 7th, 1898.

A regular meeting (the 396th) of the society was held in its hall on Wednesday evening, 7th of December, 1898. President Alfred Noble in the chair; 38 members and guests present.

The minutes of the previous meeting were read and approved.

The secretary reported for the Board of Direction, the election on the 6th of December of the following applicants to date, January 1st, 1899: As associates, F. B. Macomber and Gustavus J. Johnson; as juniors, Chas. S. Drake, Morris K. Trumbull, Geo. F. Anderson, Arthur N. Dunaway, Henry H. Lotter, Mark W. Tenny, Theodore J. Klossowski. Applications were received from Chas. S. Knapp, for admission as a junior; Frederic K. Vial and Alfred Ernest Harvey for active membership, and Saml. T. Rowley for associate.

The president called upon F. C. Rossiter to present resolutions relating to a desired appropriation for the Agricultural College at Urbana, Ill.

The secretary read letters specifying the needs of the college. Mr. Rossiter then moved that the resolutions accompanying the letters be approved by the society. The secretary was called upon to read the resolutions. After the reading, the motion was seconded by Mr. Randolph. On their adoption the motion was put and carried.

The first paper of the evening—The Manchester Ship Canal, prepared by Mr. Elmer L. Corthell—was read by Mr. W. J. Karner in the author's absence.

The next paper was by Mr. D. W. Mead, on "Mechanics of Suction and Suction Pipes;" as copies of this paper had been sent to all members, only an outline was given and special points dwelt upon by the author. Messrs. E. E. Johnson, Dabney H. Maury, Jr., and Prof. Chas. V. Kerr discussed the paper.

The president then read an extract of a paper on "Stadia Diagram," prepared by Mr. M. K. Trumbull, and also part of a written discussion of the same by Mr. Charles L. Harrison.

Adjourned.

SPECIAL MEETING—DECEMBER 21st, 1898.

A special meeting (the 397th) of the Society was held in its hall on Wednesday evening, 21st of December, 1898. There being no officers present the secretary called the meeting to order, and Mr. Emil Gerber was elected to the chair.

The paper of the evening was on "The Kinzie Street Drawbridge"—by Mr. Wm. H. Finley, Mem. W. S. E.

The subject was taken up and fully illustrated with stereopticon views. At the conclusion of the reading discussion was invited and participated in quite freely by Messrs. Modjeski, B. B. Carter, Schaub, Finley, Onward Bates, Nichols, Gerber, Liljenerantz, Wescott, Artingstall, Reichmann, Bush.

Adjourned. NELSON L. LITTEN, Secretary.

At a *SPECIAL MEETING*, held in the Society Hall, June 11th, 1898, Prof. N. O. Whitney, of University of Wisconsin, entertained most delightfully an enthusiastic audience of ladies and gentlemen with an illustrated lecture on "Three Months Among the Engineering Works of England and France."

LIBRARY NOTES.

The Library Committee wishes to express thanks for donations to the library. Back numbers of periodicals are desirable for exchanges and aid in completing valuable volumes for our files.

Since the last issue of the Journal, we have reeeived the following as gifts from the donors named:

Board of Health, Mass.—29th Annual Report for 1897-8.
N. E. Coast Institution of Engineers and Shipbuilders New Castle-upon-Tyne, England—Transactions—1897-8, Vol. XIV.
Wm. R. Hill—9th Annual Report of the Syracuse (N. Y.) Water Board, 1898.
Wm. R. Hill—Some things that should be done in constructing a Distributing System of Water Works.
E. A. Birge, Director Wis. Geol. & Natl. History Survey—Instincts and Habits of the Solitary Wasps.
Institution Civil Engineers, London—Minutes of Proceedings—Vol. CXXXIV, issued October, 1898.
Brief Subject Index Vol. CXIX to CXXXIV.
Charters, By-Laws, List of Members, 1 Oct., '98.
Street Ry. Review—Inter State Commerce Com'n, 1891-3-4-5-6.
Penn. Annual Report of the Sec'y of Internal Affairs, Part IV, 1896-7.
Description of the Cable system Chicago City Ry.
Am. Water Works Ass'n—Proceedings 8th Annual Meeting held at Buffalo, N. Y., June 14 to 18, 1898.
Dept. Interior, U. S.—Bulletins of U. S. Geological Survey, 150 to 156, inclusive.
Railroad and Warehouse Commission of Illinois—28th Annual Report, 1898.

NEW EXCHANGES.

The Institution of Mechanical Engineers—Proceedings February and April 1898, Vol. 1 and 2.
New England Water Works Ass'n.—Jonrnal No. 1, Sept., '98.
Boston Journal of Commerce—Weekly.

The library and reading rooms are open from 9 a. m. till 5 p. m. every week day, except Saturday till 3 p. m.

NELSON L. LITTEN.
Librarian.

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Vol. III.—January to December, 1898, inclusive.

ABSTRACTS.